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Proceedings— Symposium on the Biology of *Atriplex* and Related Chenopods

Provo, Utah, May 2-6, 1983

FOREWORD

Members of the plant family Chenopodiaceae, or chenopods, are found in salt deserts throughout the world. They are represented by a variety of growth forms including low annual herbs, perennial herbs, halfshrubs, shrubs, and, rarely, small trees. Chenopods are a unique family of plants with many physiological, morphological, and genetic adaptations and characteristics that enable them to survive and even flourish in highly stressful conditions of moisture, salinity, soil pH, temperature, and animal use. They are most commonly found in waste places, saline areas, and in desert and semidesert environs.

There is growing recognition throughout the world, particularly in areas suffering from desertification, of the value of chenopod plants for revegetation of harsh, highly disturbed sites. There is also a mounting concern for adverse changes that are taking place in communities of chenopod plants as a consequence of management and development activities.

Through the past several decades, a substantial amount of research has been conducted in habitats where chenopods occur. Management programs have intensified to explore their utilization for revegetation, range livestock, fuelwood, and wildlife. However, to date, there has been little effort in western North America to bring this information to the individuals involved in research and management of chenopods.

This symposium is intended to provide scientists, educators, and wildland managers with the most advanced knowledge and technology to use and manage this diverse and unique plant family. These proceedings contain a wide spectrum of information including basic physiological functions, genetics and evolution, ecological relationships, animal relationships, and management procedures.

Approximately 120 to 150 participants from land management agencies, colleges, universities, and Federal research organizations attended the symposium and field trip.

Proceedings—Symposium on the Biology of *Atriplex* and Related Chenopods

Provo, Utah, May 2-6, 1983

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INTRODUCTORY REMARKS

Douglas F. Day

I am pleased to join this esteemed group today. I welcome you to Utah to this symposium which is dedicated to a very important group of shrubs, the chenopods.

The large amount of interest in shrubs that this group is demonstrating is most gratifying. Habitat is the foundation of big game management in Utah. Shrubs occupy the major portion of our fall, winter, and spring ranges and all of our desert big game ranges.

It is meetings like this, and the work that precedes and follows them, that make my job as an administrator easier and much more fulfilling.

Twenty-eight years ago a joint big game winter range improvement research project between the Intermountain Forest and Range Experiment Station and the Utah Division of Wildlife Resources (then, Fish and Game) was begun. This cooperative effort has proven to be one of the most productive range improvement projects in North America.

When the joint effort started, little was known regarding how to improve ranges for big game or even what constituted ideal game range. Our joint efforts have resulted in the development of techniques, procedures, equipment, and plant materials that are being used throughout North America and the world for improving big game and livestock ranges and for rehabilitation of disturbed lands.

Results of much of this work, a summary of a quarter century of research and experience, will soon be published. This book will include: (a) principles and procedures of range rehabilitation, (b) descriptions, characteristics, and potential use of over 400 plant taxa, (c) characteristics and uses of equipment and techniques in range rehabilitation, and (d) guides for seeding all major range types from the subalpine down to and including the blackbrush.

One of the major objectives of the Division is the acquisition and improvement of big game ranges. Why do we place so much importance on big game range improvement and habitat management? Big game are important to Utah and to its citizens. The esthetic value of big game is immeasurable. Big game provide a good percentage of Utah citizens with quality recreation. License revenues from big game permits provide over 45 percent of the Division's income. The number of people who receive recreation opportunities and the revenue derived from licenses for each species are:

Species	No. License Holders	Cost of Licenses
Mule deer	200,000	$5,000,000.00
Elk	23,000	800,000.00
Antelope	450	12,000.00
Moose	110	11,000.00
Buffalo	28	8,500.00
Desert Big Horn sheep	11	25,000.00
Rocky Mountain goat	1	200.00
	223,600	$5,856,700.00

An important benefit that has been derived from range improvement efforts has been enhanced watershed protection and improvement.

One of the most important results of our joint research has been gaining a firm appreciation of many plant taxa. We are meeting today to bring together those who are interested in *Atriplex* and related chenopods. There is more potential within the chenopod family for use in rehabilitation of disturbed lands in the West than in any other plant family. A majority of our desert deer and antelope ranges, along with the foothill winter ranges of central and northeastern Utah, are inhabited by or adapted to *Atriplex* and related chenopods.

It is most fitting that this group has assembled here this week to expand our knowledge and understanding of *Atriplex* and related chenopods.

Douglas F. Day is Director of the Utah Division of Wildlife Resources, Salt Lake City, Utah.

A TOUR OF CHENOPODS IN WESTERN UTAH

Howard C. Stutz

As a part of the symposium on "Atriplex and Related Chenopods", May 2-6, 1983, a 2-day field trip was conducted in western Utah. Nearly every major chenopod genus and most of the major chenopod species of western America were seen. To provide a review of the trip for the participants and an opportunity for a self-guided tour for others who may wish to become better acquainted with this remarkable group of plants, this short essay has been prepared, describing the major populations which were visited. Because of the muddy roads encountered on the tour a few sites which had been included in the original plan were not visited; however, descriptions of some of these are included to make the review that much more complete.

The field trip begins in Rush Valley, about 40 miles (64 km) west of Provo. To get there from Provo, it is best to go by way of Lehi, Cedar Fort, and Fairfield on Utah Highway 73. This cuts through Cedar Valley west of the Oquirrh Mountains. Until recently Cedar Valley contained mature native stands of sagebrush and greasewood but has now been turned mostly into agriculture.

Rush Valley begins at the Utah-Tooele County boundary. Almost the entire chenopod tour will be within Tooele County. Like most valleys of western Utah and Nevada, Rush Valley extends north and south with steep mountains on each side. The bottom lands are occupied almost exclusively by chenopods; the lower slopes have a mixture of chenopods and composites (notably Artemisia, Chrysothamnus, and Tetradymia); junipers and pinyon pine dominate the upper slopes.

Stop #1: Diploid Atriplex confertifolia

The first stop on the tour is about 1 mile (1.6 km) west of the Utah-Tooele County line. To get there, turn onto the road to Faust and proceed 0.5 mile (0.8 km) west. As for most of the tour stops, it is best to leave the car and walk out into the vegetation. As you walk out to the north of your car you will encounter several plant species which will be present throughout much of the tour. The most conspicuous shrubs are Artemisia tridentata Nutt. var. wyomingensis (Torr. & Frem.) Wats., Chrysothamnus viscidiflorus (Hook) Nutt. var. stenophyllus (Gray) H. M. Hall, and Atriplex confertifolia (Torr. & Frem.) Wats. The most common perennial grass is Oryzopsis hymenoides (R. & S.) Ricker (Indian ricegrass).

Atriplex confertifolia (shadscale) here is diploid (2N=18 chromosomes). Notice that the plants are widely spaced, vigorous, 15-30 inches (38-76 cm) tall, and very thorny. This is the general appearance of all diploid populations of shadscale. Polyploid populations, as you will see later, usually grow in dense, uniform, crowded populations in association with very few other species. Polyploid plants are also smaller in stature than diploids. Throughout the tour, the diploid form of shadscale will be routinely encountered on the upper valley slopes in association with sagebrush, rabbitbrush, and junipers as seen here. Populations of shadscale in the bottom lands are all polyploids (2N=36 or 2N=72 chromosomes).

Stop #2: Atriplex falcata, Ceratoides lanata, and Experimental Plantings

To get to Stop #2, continue westward on the Faust road for 1.5 miles (2.4 km) where there is a dirt road to the right (north). Follow this dirt road for 3.5 miles (5.6 km) where you will come to three USDA Forest Service fenced exclosures in which are planted several species of shrubs. Among them are some chenopods which might interest you.

As you approach the exclosures, stop and walk out toward the south side of the first (southernmost) exclosure. You are now in an almost pure stand of Atriplex falcata (Jones) Standl. It is one of the smallest statured of all perennial Atriplex and in midwinter or very early spring is often quite obscure. However, it begins its spring growth very early and is conspicuous and beautiful by early June. Fruits usually mature by late June or early July.

Plants in this population are diploid (2N=18). Some other populations are tetraploid (4N) with 36 chromosomes and some are hexaploid (6N) with 72 chromosomes, but most populations are diploid. A few miles from here is one of the hexaploid

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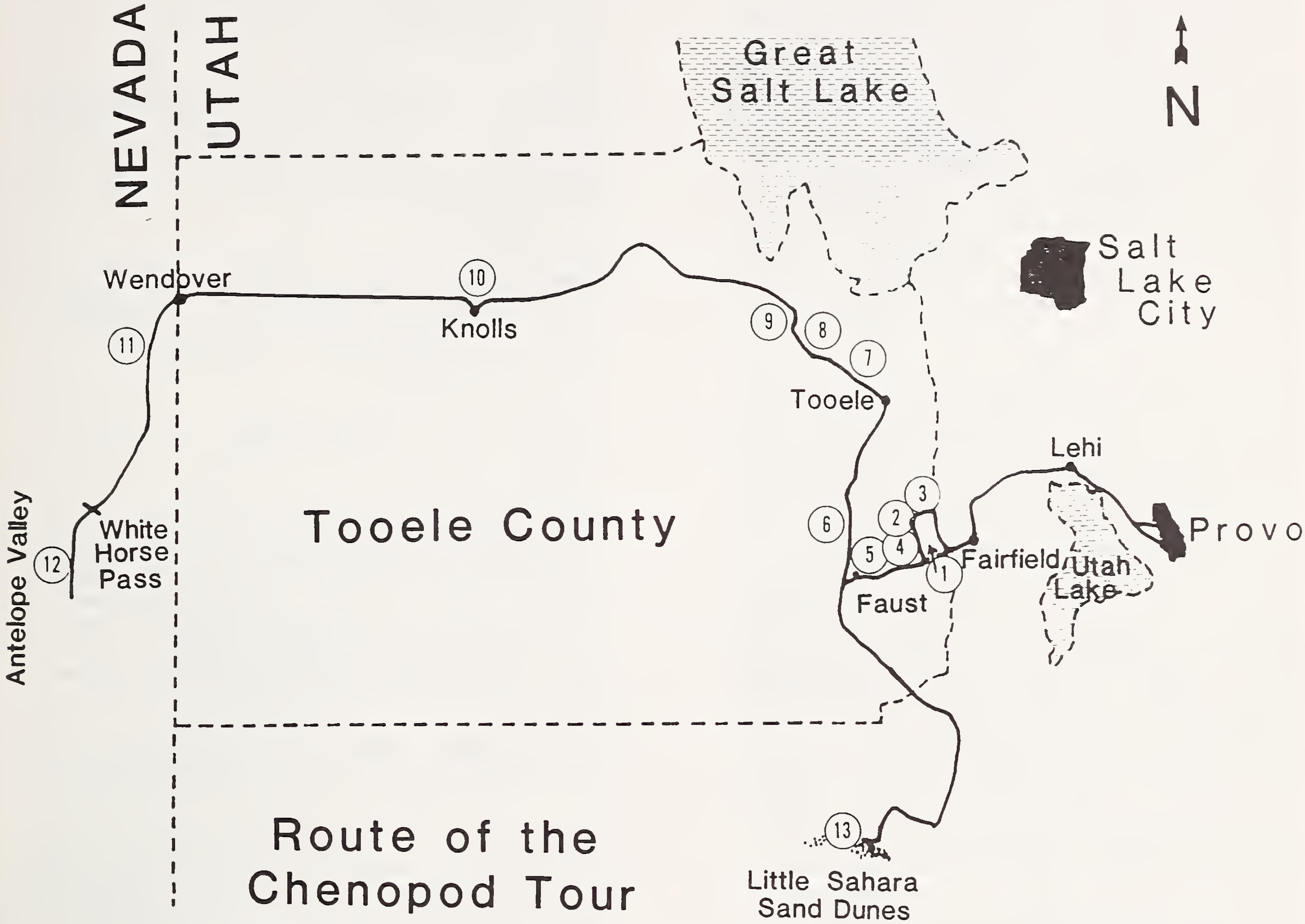
This paper is the result of an invited account of the field tour of May 3 and 4 especially modified for "do it yourself" visits.



Route of the Chenopod Tour

Showing the location of the major stops

(6N) falcata populations which we will visit later on today. Diploids occur in dense patches like this throughout southern Oregon, southern Idaho, northern Nevada, and most of Utah. They look quite different from population to population, but all have in common the early flowering habit, a pronounced taproot system, tiny linear leaves, and small-beaked fruits. It is thought that A. falcata was derived from a more northern highly variable species (the proposed name for it is A. "canadensis"[1] but is not yet published). A. "canadensis" appears to be ancestral also to A. gardneri (Moq.) D. Dietr. and to A. tridentata Kuntze. A. gardneri is found only in more northern latitudes (Montana, Wyoming, North and South Dakota) so will not be encountered today but, A. tridentata is abundant in Utah and Nevada and will be present in most of the valley bottoms throughout the tour.

Because Atriplex falcata usually grows on high-quality silty-loam soils, much of it has already been destroyed by the recent spread of agriculture and by the widespread introduction of crested wheatgrass. It is also highly palatable and highly nutritious which, in association with its early spring flush of growth, has made it a much preferred species for early spring grazing. This appears to have also taken a large toll.

Another prized chenopod, which has taken abuse for the same reasons, is abundant immediately to the north of where you are standing. All of that beautiful light-gray vegetation is Ceratoides lanata (Pursh) J.T. Howell (winterfat). It too is palatable, nutritious, grows on some of the best soils, and, being evergreen, is preferentially sought out for winter and early spring grazing, apparently much to its detriment.

Ceratoides lanata is almost always diploid (2N=18). But it doesn't want for genetic variation by other means. It has apparently accumulated numerous mutations. It shows variation in many characteristics but is particularly strikingly variable in its stature. Some populations consist of plants that grow to 20 to 30 inches (50 to 75 cm); in other populations plants seldom exceed 4 inches (10 cm). The stature of the plants in the population in which you are now standing is quite typical for most populations throughout western Utah. But throughout its wide range from Alaska to Mexico, many ecotypes have evolved. It should be very easy to select strains which would be superiorally adapted for use on particular sites.

[1] In this article I have used several tentative species names which have not yet been formally published. These are A. "canadensis", A. "dollyvardensis," A. "robusta," and A. "tooelensis." One tentative subspecies is A. canescens (Pursh) Nutt. var. "gigantea."

Stop #3: Grayia spinosa (Spiny Hopsage)

There is a small population of Grayia spinosa (Hook.) Moq. about 1 mile (1.6 km) east of here. To get to it, drive about 0.10 of a mile (.16 km) north and then turn east on a winding dirt road. This road will lead back to the asphalt, but about halfway there it traverses a nice population of G. spinosa. As you drive, notice the extensive populations of Ceratoides. They appear as rivers flowing down the gentle slopes, alternating at times with A. falcata, sometimes with cheatgrass (Bromus tectorum L.) and sometimes, particularly farther up on the slopes, with sagebrush.

Notice also as you drive toward the Grayia population that you go through some populations of large Artemisia tridentata var. tridentata. These are usually diploid, whereas the shorter statured A. tridentata var. wyomingensis is usually tetraploid.

The appearance of Grayia spinosa varies from season to season, but it is usually strikingly different from all of its associates, so there is usually no difficulty in picking it out. Its bark is quite distinctly gray-purple. In winter and spring the buds look like tiny white cabbages scattered alternately along the thorn-tipped branches. When in leaf, the broad succulent leaves are very distinctive, and when in fruit (in early summer) the large variously colored bracts give a spectacular show which attracts one's attention even when far off.

Grayia spinosa is an evolutionary puzzle. There are no clues to its ancestry. It stands alone in almost every attribute from all other chenopods. It is nutritious and palatable, but its thorns usually keep it from being utilized. It usually grows in soils less alkaline and less salty than those tolerated by other chenopods. It sometimes grows in extensive populations but is also commonly found in small clusters like this somewhat isolated population.

Another mile (1.6 km) up the road (going east) you come again to Highway 73 (asphalt). If you were to follow it to the north it would bring you to Tooele. But instead, turn south and go back once again to the Faust exit (about 4 miles, 6.4 km) where you will once again turn to the west and go down into the valley bottoms. Notice as you travel back to the Faust exit that the highway traverses a rich mixture of sagebrush, rabbitbrush and diploid shadscale, similar to that at the first stop.

Stop #4: Kochia americana and Sarcobatus vermiculatus

At the Faust exit, make a sharp turn to the right (west) and proceed for 2.5 miles (4 km) to a nice population of the chenopod Kochia americana Wats. It is best developed on the north side of the road opposite a conspicuous clay mound.

Kochia americana is the only perennial species of Kochia in America and is remarkably unknown. Few plant species enjoy such anonymity. Essentially nothing is known of its genetics, evolution, physiology, or ecology. This is the most extensive population that I know of, but it is common as a minor component on many of the chenopod-occupied lands of western North America. Usually, a few plants will be found here and there on the harshest sites.

Being deciduous and of small stature, K. americana is utilized very little by herbivores. It has bisexual flowers and because of its apparent uniformity, is probably sexually self-compatible.

On the south side of the road, around the clay mound and extending far up into the valley, is a large population of Sarcobatus vermiculatus (Hook.) Torr. (greasewood). Because of its large stature (3 to 8 feet, 1 to 3 m) and extensive stands, S. vermiculatus is one of the most conspicuous of all chenopods. It is most commonly found in sites such as this where salinity and ground water are both high. In some places it becomes abundant on valley slopes and on small sand dunes, but even in those situations the deep extensive root system is probably in water.

Throughout the remainder of the tour, greasewood will be encountered many times. In some places it is very heavily grazed. Some stands have been burned and some railed in attempts to get rid of it, but it is hard to remove. Some users like it, some curse it. It has been reported to be toxic to livestock, particularly when it has been the sole source of forage. In mixtures, toxic effects are apparently minimal.

All of the greasewood populations in the Great Basin that have been sampled thus far for chromosome studies have been octoploid (72 chromosomes). Populations that have been examined in Alberta, Canada, have all been tetraploid (36 chromosomes). We are actively searching for diploid populations which we expect occur somewhere in the geographical distribution of Sarcobatus.

Stop #5: Polyploid forms of Atriplex confertifolia and Atriplex tridentata

These are located 2.5 miles (4 km) farther west near the Pony Express monument. Upon arriving at the Pony Express monument, exit to the right (north) and follow the dirt road for about 50 yards (45 m). You are now in the midst of an extensive population of polyploid A. confertifolia (shadscale). Notice how uniform and dense the stand is. Glance up the valley to get a feel for the expanse of the population. Notice that most plants are about the same size, all are at about the same stage of growth and phenology. Very few other species are here.

Can you recall the diploid population? Diploid A. confertifolia plants were widely spaced, of various sizes, intermixed with many other species.

Polyploidy in this species, and apparently in most other woody chenopod species, brings with it genetic uniformity, reduced stature, and increased woodiness. Polyploids are always produced from a very small proportion of the genetic variation which is present in their diploid progenitors so are routinely very uniform. This causes them to be ecologically narrow-niched but often superbly so. Consequently polyploid populations such as this essentially saturate the landscape to which they are uniquely adapted. Diploids, being genetically flexible, occupy a variety of sites in conjunction with and in competition with a number of other species. They are therefore marvelously endowed with the capacity to accommodate changing environments. Polyploids are not. When the environment to which a polyploid is adapted changes, the polyploid is usually lost.

This is probably the principal reason for the distribution pattern of shadscale which we have thus far seen on the tour. The diploids are on the upper slopes, mingled with a variety of other shrubs, occupying a wide variety of microenvironments. They are in terrain that was above the level of the Pleistocene lakes which filled these valleys as recently as 10-12,000 years ago. They were probably in these same sites even during those pluvoglacial times. As the water receded, extensive acreages of highly uniform empty terrain became suddenly available. Each adaptive polyploid, being genetically uniform, could explosively spread out and occupy vast domains. Predictably, as successional competition unfolds during the coming centuries, many of these uniform polyploid stands will be replaced. But today we are privileged to witness the early moments of this dynamic drama and the adventive polyploids coming forth from their diploid ancestors in the adjacent junipers and sagebrush uplands.

About 0.5 mile (0.8 km) farther north, polyploid Atriplex confertifolia intergrades with, and then gives way to, a pure stand of Atriplex tridentata (Kuntze) H. and C. This is the hexaploid (6N) form which is so common in the bottom muds of old Lake Bonneville. Diploid (2N) and tetraploid (4N) forms of A. tridentata occur in Wyoming and Montana but the hexaploid is the only form here in these bottom lands which were covered by water only a few thousand years ago. A. tridentata probably came into Utah as a hexaploid and, as did the polyploid forms of shadscale, spread rapidly to occupy the rather uniform empty lake muds. It apparently is now being replaced in some places by saltgrass (Distichlis stricta (Torr.) Rydb.) and Sarcobatus vermiculatus.

Atriplex tridentata is highly palatable and nutritious. Most ranchers who have it hold it in high esteem as a forage plant. But in some places it appears to have already been grazed out and in others is being seriously threatened. Some populations would probably have long ago been destroyed were it not for its vigorous root-sprouting habit.

The rest of the large valley to the north is occupied by alternating bands of A. confertifolia, A. tridentata and Sarcobatus vermiculatus. If you would like, drive on up through them to acquire an appreciation for their magnitude and importance. For the tour, however, we will turn around here and return to the Faust road.

At the monument, turn right and proceed west toward Faust. As you drive along notice that each deep valley is occupied by polyploid A. confertifolia and A. tridentata. On the knolls, Artemisia and Chrysothamnus become abundant.

After crossing the railroad tracks at Faust, go about 0.5 mile (0.8 km) before stopping in another rather distinctly different population of polyploid A. confertifolia. Although it is a uniform stand, as was the population at the Pony Express monument, the plants are noticeably larger and more widely spaced. To the south you can see some scattered junipers. Diploid (2N) A. confertifolia plants also grow there among the junipers. It is remarkable how these different habitats are neatly matched by different chromosome races.

Stop #6: 6N Atriplex falcata

At the junction of the Faust road with Utah Highway 36 (asphalt), turn right and proceed 7.5 miles (12 km) to a "pure" stand of hexaploid A. falcata. It is easily spotted on the west side of the road as a low-growing light-colored carpet. The borrow pit is shallow so, if you wish, you can easily drive out into the Atriplex. Notice how flat and level the ground is. Can you tell why? Did you ever see a more beautiful homogenous stand of anything? This is one of my favorite overnight fireless campsites. It's so clean and handsome.

This is the only known population (or series of populations) of the 6N form of A. falcata. It has many things in common with the diploid form which we saw back at the Forest Service exclosures, but it is somewhat more woody and longer lived. Notice how abruptly it interfaces with the neighboring sagebrush. Is it invading the sagebrush? Or is the sagebrush invading the Atriplex? So far it has not been possible to detect the factors which give it such sharp borders. There doesn't appear to be any measurable edaphic factor or moisture difference. Probably the best guess is simply that it is here because it arrived first and has proven very competitive. There has not yet been time for successional processes to cause changes in composition.

As you travel on toward Tooele, a few more rivers of 6N A. falcata can be seen off to the west, but soon the landscape becomes dominated by vast populations of sagebrush and shadscale.

Tooele is the last major city on the tour until Wendover so it would be well to freshen up and gas up here before continuing.

Stop #7: Atriplex "tooelensis": A New Species.

About 6 miles (10 km) west of Tooele on highway 112 there is a "brand new" species of Atriplex. You can get a good look at it by stopping about 50 yards east of mile marker #2 east of Grantsville. It is present on both sides of the road. From a distance, it looks a good deal like A. canescens. Notice that the plants are well spaced and rather distinctly separated from the contrasting surrounding grasslands. This new species (currently referred to as Atriplex tooelensis) is a product of the hybrid A. canescens x A. tridentata. This same parentage has given rise to several other new species and a host of genetic variables from which even other species may yet be derived. We will see some more of them during the next few hours.

A. tooelensis is hexaploid (6N) like its A. tridentata parent. It has four-winged fruits like its A. canescens parent, although the fruits are smaller and irregular. Most of its other features are mosaics of the two parents or else show intermediacy. The A. canescens parent prefers sandy soils whereas A. tridentata is almost always in heavy clay soils. The soils here which are occupied by A. tooelensis is a clay loam, intermediate between those required of the parents. Flowering and fruiting time of A. tooelensis is late in the season like its A. tridentata parent. Its woody habit is more like its A. canescens parent.

Many other genetic combinations can result from the hybrids between these strikingly different parents but this particular segregant appears to be marvelously suited for this particular site. As you can see, the total population occupies not much more than 100 acres (40 ha). It is probably only a few decades old.

Stop #8: Ecological Zonation of Chenopods

About 4 miles north of Grantsville on Highway 138, the road comes close enough to Great Salt Lake to permit a look at the lakeside vegetation zones. Usually it is possible to exit on the turnoff to the east. If it is not too muddy, you can drive down onto the lake muds about 0.2 mile (0.3 km), but if it's muddy just park and walk down. This is an excellent place to see several important chenopods and also to see how they are restricted to specific ecological zones.

Farthest out into the wet muds is Salicornia pacifica Standl. (samphire). It has jointed stems, very succulent leaves and opposite branching. It is the only chenopod shrub which can accommodate prolonged submersion in these saline waters. Its monotonous uniformity in habit is, undoubtedly, a reflection of its uniform genotype which is a consequence of inbreeding.

Around the wet edges of the meadows of Salicornia is Allenrolfea occidentalis (Wats.) Kuntze (pickleweed). It also is often submerged in salt water but not for such prolonged periods as Salicornia. Although not particularly abundant right here, in many places on the shores of the Great Salt Lake, its preferred habitat is extensive and vast acreages are occupied by nothing else.

Notice that, like Salicornia, its stems are jointed and the leaves are succulent. But it differs from Salicornia in that the branching is alternate. It also stands much more erect and is considerably more woody than Salicornia. It too is genetically uniform and is consequently restricted to a narrow ecological niche.

Altitudinally above Allenrolfia is Atriplex tridentata. There is not much of it right here in this severely protracted shoreline, but in other such places it is often very abundant.

Next, up on the slopes, comes Sarcobatus. These large thorny bushes often form almost impenetrable thickets. They sometimes extend in a belt around the lake often a half mile (0.8 km) or more wide and 10 to 20 miles (15-30 km) long.

Above the Sarcobatus and sometimes growing right with it is Atriplex confertifolia.

In many places around the lake, this distinct zoning from Salicornia to Allenrolfea to Atriplex tridentata to Sarcobatus to Atriplex confertifolia is clear and distinct. Sometimes Atriplex and Sarcobatus intermingle and sometimes Salicornia and Allenrolfea intermingle but in most places they stay "where they belong."

Stop #9: An Isolated Female A. canescens Plant. (Where It All Began)

About 5 miles (8 km) farther north on this same highway (Hwy 138), there is an old railroad loading dock on the west side of the road, about 0.3 mile (500 m) south of the freeway. If the metal gate is open (it usually is), drive in and around to the far side of the loading dock. If the gate is closed, it is only a 3-minute walk. Nestled against the west embankment of the dock is a single, large female plant of Atriplex canescens. This plant bears some significant sentimental value. It was here that many of these chenopod studies got their start.

Early in our studies, seeds were collected from this particular bush as just one of the many others which we had sampled during a broad survey of the chromosome numbers of Atriplex canescens. Earlier we had found a diploid (18 chromosomes) form of A. canescens growing on the Little Sahara Sand Dunes in central Utah. All other populations which had been examined had only tetraploid (36 chromosomes) plants. When we came to this large plant growing on sand we wondered if it might be another diploid. Much to our surprise, seedlings from this plant all had 45 chromosomes! After considerable deliberation we decided that such a product could only come from a 36 chromosome x 54 chromosome parentage. So if this plant had 36 chromosomes, like that of most A. canescens plants, its sex cells would consequently each have 18 chromosomes and seeds having 45 chromosomes would be produced only if the other parent had 54 chromosomes: (its pollen would have 27 chromosomes; 18 + 27 = 45).

Since this is a lone female plant, and since the only other Atriplex species anywhere near is A. tridentata, we then reasoned, A. tridentata must be the culprit and it must be hexaploid (54 chromosomes). We didn't waste much time in checking it out. A. tridentata is indeed hexaploid! Furthermore, we found a few hybrid seedlings nearby and raised some others in the Brigham Young University nursery. From this beginning we have learned much about their fertility and potential for yielding new species, such as A. "tooelensis which we saw a few miles back.

Stop #10: The Origin of Atriplex robusta

Another new species that has recently evolved from A. canescens X A. tridentata parentage is A. "robusta." It is of very recent origin; so recent that its progenitors are still in place. It originated near Knolls, Utah, a small community about 40 miles (64 km) west of here. To get there, follow the freeway (I-80). There is an entrance to the freeway about 0.5 mile (0.8 km) north of here.

On the way to Knolls, you will see several large populations of various chenopods. One of the first is Salicornia. Lots and lots of it is growing in the wet borrow pits for the first 5 or 6 miles (8-10 km). In drier sites Allenrolfea occidentalis, Atriplex tridentata and A. confertifolia are common. Just past the Rowley exit, a large population of 8N Atriplex confertifolia can be seen off to the north.

After leaving Delle, the road rises gently to the Lakeside exit. Notice how, with increasing altitude, more grasses and fewer chenopods are present. Occasional large patches of A. confertifolia can be seen on the bottom floor or along the sides. The sharp boundaries of these populations suggest a dramatic interaction with the grasses but it is difficult to determine which way the drama is proceeding and which will be the ultimate winner.

After exiting at the Knolls exit, if traffic will permit, make a brief stop up on top before going across the overpass. From here you can see Allenrolfea occidentalis at its best. Off to the northwest as far as you can see there is nothing but Allenrolfea. This area is often flooded, but not for long. Allenrolfea's feet are always in the water; at times it's nose is too. Wherever it gets wetter, it is replaced by Salicornia; wherever it gets drier it is replaced by Sarcobatus, Suaeda or Atriplex. Off to the northeast can be seen an extensive stand of Halogeton, a troublesome introduced annual chenopod.

After leaving the overpass, the road turns west and cuts through a sand dune just before coming to Knolls. Stop on the east side of the dune for a look at a nice population of Atriplex canescens. This is one of the parents of A. "robusta." Notice its vigor. The plants appear to have many of the same characteristics found in the diploid (2N) A. canescens var. gigantea which grows on the Little Sahara Sand Dunes 100 miles (160 km) south of here. But these plants are tetraploid (4N). There is good reason to believe that these may be autopolyploids derived from the gigas diploids.

About 50 yards (45 m) to the west (you can either drive or walk) are some plants of A. tridentata, the other parent of A. "robusta." Nearby are extensive populations of A. tridentata but here you can see only a few of them. Also here is a variety of A. canescens X A. tridentata hybrids and hybrid products. Notice how each plant differs in stature, in habit, in woodiness, in leaf size and texture, and in fruit characteristics. Take plenty of time for "oohing and aahing," then go out into the median between the two freeway lanes immediately north of here where more of these hybrids can be seen. To get there, return to the overpass, cross over, and return to the sandhills by way of the freeway, then exit into the wide, well-traveled median.

In this median area, there are even more segregants from A. canescens X A. tridentata hybrids and, in addition, one form that recurs over and over again. This is the one and only segregant, among the hundreds which are possible, which so far, is sufficiently adapted to this particular habitat to have become established as a new species-- Atriplex "robusta". As you travel on down the freeway from here, you will see it over and over again. There are now thousands and thousands of them. Some have gone nearly to Wendover, 30 miles (50 km) to the west. Some have gone nearly to Delle, 40 miles (64 km) to the east. They occur only along the freeway and the freeway is less than 20 years old!

Here, then, is evolution in action. A new species is born, right before our eyes!

As you continue west on the freeway, notice that A. "robusta" is very common in some places, scarce in others. Can you guess why? Stop occasionally and take a close look at this remarkable segregant. Notice that its leaves are larger in all respects than the leaves of either of its parents. (That's hybrid vigor!) The fruits are distinctly three-toothed (sometimes more) like its A. tridentata parent, but they are at least three times as large. The plants are quite woody, a characteristic which they received from the A. canescens parent. They are also hexaploid (6N) like the A. tridentata parent.

Along with A. "robusta", a few unusually large hybrid Atriplex plants are also present on the highway shoulders. An examination of their fruits, leaves, and woodiness clearly indicates that they are backcrosses of A. "robusta" onto A. canescens. These differ considerably from plant to plant, but although they have fairly high seed fertility, they do not appear to be producing anything of significance in this environment.

The only other species that are at all conspicuous along the freeway are Allenrolfea occidentalis and, occasionally, a few plants of Suaeda fruticosa.

While you are here in this remarkable landscape, where the narrow ribbon of asphalt traverses vast expanses of salt and water, be sure to contemplate some of the other unusual spectacles. Notice, for instance, that this great expanse of salt and water is so extensive and so level that you can actually see the curvature of the earth! Also notice the logs, mountains, and bushes hanging in the sky near the horizons. The Utah Travel Bureau has gone to great expense to have this prepared just for your visit.

Our next chenopod stop is on the other side of Wendover. You will probably want to spend the night in Wendover before proceeding, but the account of the tour will continue as though we were to just keep going.

Stop #11: A rich mixture of A. canescens, A. confertifolia, and A. tridentata

Starting at about 3 miles (5 km) south of Wendover on U.S. Highway 93A, Atriplex canescens becomes increasingly abundant in the borrowpits. On the gentle east-facing slopes, above the road, A. confertifolia also becomes abundant. This population of A. confertifolia is another octoploid form, but notice how very different it is from the other octoploid populations which we have seen. This small-statured, very compact, very woody, very spiny form is admirably suited to these xeric, harsh exposures. Other forms probably wouldn't make it here at all nor would this form likely succeed in their habitat. Just as there are numerous ecological sites throughout the Great Basin to which Atriplex confertifolia is adapted, so there are numerous genetic strains to match them. Patchy environments invite patchy taxa.

Coming up from down near the lake are several rivers of A. tridentata. Here, where all three of these Atriplex species meet (A. canescens, confertifolia, and tridentata), hybrids occur among all of them. No new stabilized derivative is yet apparent, but the potential is certainly present. If (or when) the right combination comes along, it could easily and quickly provide a new adaptive taxon. In the meantime, subtle introgression of genes from each of these species into the others is permitting less dramatic, but every bit as effective, evolutionary change. The most noticeable introgression here is that of A. confertifolia into A. canescens. Because of this introgression, A. canescens is beginning to creep up the mountain. Such harsh, xeric sites could never be occupied by ordinary A. canescens, but given some A. confertifolia genes, they are apparently going to make it.

Stop #12: Atriplex dollyvardensis, another new species.

There is a large population of Atriplex "dollyvardensis" in Antelope Valley, about 20 miles (30 km) south of here. On the way to Antelope Valley, you will drive through a rich mix of wildland shrubs including several chenopods. At the upper slopes, Grayia spinosa is intermittently common along with Tetradymia spinosa H. & A., T. glabrata Gray, and Artemisia spinescens D.C. Eaton. Probably the most abundant non-chenopod shrub throughout this entire area is Chrysothamnus viscidiflorus var. stenophyllus.

Just beyond White Horse Pass, as you enter Antelope Valley, vast populations of several species of chenopods can be seen from a distance. They appear as alternating bands extending across the valley slopes. The lighter colored bands are Ceratoides lanata. There must be thousands and thousands of acres of it here. The extensive dark-gray bands (in winter and spring) are populations of Atriplex confertifolia. Sarcobatus vermiculatus appears from here as dark green bands.

Atriplex "dollyvardensis" appears as conspicuous, extensive light-gray weeds. There are thousands of acres of it. To become better acquainted with it, drive down to the bottoms and stop at about mile marker #18. Off to the west it is in almost pure culture. As you walk out into it, you will see that it is very woody. Most plants are about 20 inches (50 cm) tall. Leaves are linear and blunt. Fruits are beaked and usually highly sculptured with various protruberances.

The origin of A. "dollyvardensis" is not yet clear. Its woodiness, narrow leaves, and highly sculptured fruits suggest the influence of A. canescens. Some of its other attributes (beaked fruits, low stature, and tap roots) suggest A. falcata ancestry. Because of this and because it is hexaploid (6N), it may be an allopolyploid derived from 4N A. canescens x 2N A. falcata. But at this time, that interpretation is very speculative.

To compare it with diploid A. falcata, you may want to drive another 5 miles (8 km) due south where there is a nice clean population of A. falcata. It is located about 2 miles (3 km) south of the Dolly Varden exit on the west side of the road. Notice how it stops abruptly at the juncture with its neighbors. Notice also how much smaller, finer textured, and more herbaceous it is compared to A. "dollyvardensis". Just beyond this population, to the south, is more Ceratoides lanata and then several miles of a mixture of Grayia spinosa, Artemisia, and Chrysothamnus.

This terminates the chenopod tour. As you return to Provo you may want to review the various species which you have seen. If you can identify them at 55 mph, you know them!

Stop #13: (For good luck, and also for gigas diploid *Atriplex canescens*)

At the end of our tour in 1983, many of the participants elected to take a major additional excursion to the Little Sahara Sand Dunes to see the gigas diploid form of *A. canescens*. It's quite a long way over there but it's well worth it. For those who would like to go, here are a few directions which should increase your enjoyment of the experience.

The Little Sahara Sand Dunes (so designated by the BLM) are located in Juab County, Utah, about 20 miles (30 km) northeast of Delta, Utah. To get to them, the most direct route is to return to Tooele and then follow Highway 36 south about 50 miles (80 km) to Tintic where it joins U.S. Highway 6. Continue south on U.S. 6 for another 15 miles (24 km) where, at a crossroads, there is a well-marked sign, pointing to the "Little Sahara Sand Dunes" to the west. Cross the railroad tracks and proceed west for about 5 miles (8 km). Turn south at the sign which points to the BLM Little Sahara Recreation Area and follow the asphalt for 7.2 miles (11.6 km) to the "Jericho Picnic Area." Pull into the picnic area and park in one of the stalls facing west. Immediately in front of you, those large bushes growing on the dunes, are diploid *Atriplex canescens* var. "*gigantea*" plants. You simply must walk over and see them up close.

As you walk toward the dunes you will pass some ordinary-looking *A. canescens*. That's exactly what they are--ordinary tetraploid *A. canescens*. Every bush which is not on the dunes is tetraploid; every bush growing on the dunes is diploid. It's remarkable how they know where they belong. We have seen several other examples on the tour of such sensitive habitat sensing by specific genotypes, but none are more specific than these.

Fortunately, tetraploid and diploid *A. canescens* can be distinguished by means other than actual chromosome counts. As you examine the diploids, notice the large amount of new growth on the stem tips. New leader growth on diploids is usually at least twice as long as on tetraploids. This is also reflected in their longer internodes.

The gigas growth habit of diploids is also evident in fruit size, in leaf dimensions, and in total size of the plants. Some of the plants grow more than 8 feet (2.5 m) high and 20 feet (6 m) across. If you walk about 100 yards (90 m) to the north, you can see some of these huge plants not far away. If you are a good hiker you ought to go over for a close-up look.

Seedlings of diploids show the gigas growth rates right from the start. When grown alongside tetraploids in the greenhouse, diploids outgrow tetraploids, two to one. This differential is maintained all through their life even when transplanted to common gardens.

The gigas habit of the diploid is a bit puzzling. In most plants, diploids are *less* robust than polyploids; polyploids are usually gigas. Why then is it reversed in fourwing saltbush? The answer is not at all clear but it appears to be related to the woody habit of *Atriplex*. Most other reports of polyploidy have been from studies of herbaceous plants. Woody plants probably provide an entirely different scenario. For example, large sagebrushes (*Artemisia*), like saltbushes, have gigas diploids and smaller polyploids.

In polyploids, there is always a longer interval between cell divisions than in diploids. This is apparently simply because it takes longer to generate twice as many chromosomes prior to the next cell division. In herbaceous plants, cell growth continues during this long interval. In woody plants, however, because cellulose may be deposited in the cell walls, cell elongation may be inhibited. Some cells may even be prevented from further mitosis. As a consequence the plant may be conspicuously stunted. Whether or not this is the correct explanation awaits further information, but the remarkable reversal of gigas growth rates in these woody plants compared to herbaceous species is real.

The strict difference in habitat of diploid and tetraploid *A. canescens* is also somewhat of a puzzle. Why is the diploid so severely restricted to the sand dunes and why is the tetraploid so severely restricted to off-dune sites? The best guess which I have been able to come up with so far is that tetraploids are not on the dunes simply because they cannot grow fast enough to keep up with the ever-shifting sands. Why diploids are not found off the dunes is a little stickier but it may be that because of their increased succulence they are unusually attractive to herbivores and are therefore devoured before they can get established. They grow well in nurseries at a variety of sites; they do not need sand dune habitat for growth, so perhaps they are restricted to dunes primarily because of the refuge provided therein.

Neither is it clear where gigas fourwing came from. There are other populations of diploid *A. canescens* in southern Arizona, southern New Mexico, and Mexico but they are genetically conspicuously different from the Jericho sand dune form. Could these be relics of a formerly much wider distribution? Hopefully, answers to such questions will be forthcoming from future studies.

Because of its limited distribution, its high intrinsic academic value, and unusual esthetic worth, gigas A. canescens clearly deserves some protection. It would be a terrible loss should they ever be completely destroyed. ORV's continually take their toll. The BLM has set aside a small acreage to the north of here where ORV's are prohibited. I hope it will be enough to provide the protection needed for the survival of gigas A. canescens.

I hope you have enjoyed this brief tour into chenopod lore. The chenopods constitute a remarkable group of plants. Quite a few species of plants can handle salt, and quite a few can handle low precipitation, but the chenopods are almost alone in their capacity to handle both. No desert is quite as severe as a salt desert. Since all plants are believed to have originated in fresh water, salt deserts provide the ultimate challenge for survival on land. In that sense then, chenopods are at the latest frontiers of evolution. I salute them!

BACKGROUND REFERENCES

Flowers, S. Vegetation of the Great Salt Lake region. Bot. Gaz. 95: 353-418; 1934.

Hall, H. M., and F. E. Clements. The phylogenetic method in taxonomy. Carnegie Inst. Wash. Publ. No. 326. 1923.

Hanson, C. A. Perennial Atriplex of Utah and the northern deserts. M. Sc. thesis, Brigham Young University, Provo, Utah. 1962.

Plummer, A. P., S. B. Monsen, and D. R. Christensen. Fourwing saltbush, a shrub for future game ranges. U.S. Department of Fish and Game Publ. No. 66-4. 1966.

McArthur, E. D.; Pope, C. L.; Freeman. D. C. Chromosomal studies of subgenus Tridentatae of Artemisia: Evidence for autopolyploidy Am. J. Bot. 68: 589-605; 1981.

Pope, C. L. A phylogenetic study of the suffrutescent shrubs in the genus Atriplex. Ph.D. dissertation, Brigham Young University, Provo, Utah. 1976. 277 p.

Stutz, H. C. The meaning of Rare and Endangered in the evolution of western shrubs. In: The Endangered Species, Great Basin Naturalist Memoirs, 3: 119-128. 1979.

Stutz, H. C. Explosive evolution of perennial Atriplex in western North America. Great Basin Naturalist Memoirs 2: 161-168. 1978.

Stutz, H. C. Broad gene pools required for disturbed lands. In: Reclamation of mined lands in the southwest. Symposium. Albuquerque, NM, 113-118. 1982.

Stutz, H. C.; Melby, J. M.; Livingston, G. K. Evolutionary studies of Atriplex: A relic gigas diploid population of Atriplex canescens. Am. J. Bot. 62: 236-245; 1975.

Stutz, H. C., Pope, C. L.; Sanderson, S. C. Evolutional studies of Atriplex: Adaptative products from the natural hybrid, 6N A. tridentata x 4N A. canescens. Am. J. Bot. 66: 1181-1193. 1979.

Stutz, H. C.; Sanderson, S. C. The role of polyploidy in the evolution of Atriplex canescens. In: Arid land plant resources. Texas Tech Univ.; 615-621. 1979.

Stutz, H. C.; Sanderson, S. C. Evolutionary studies of Atriplex: Chromosome races of A. confertifolia (shadscale). Am. J. Bot. 70: 1536-1547. 1983.

In: Tiedemann, Arthur R.; McArthur, E. Durant; Stutz, Howard C.; Stevens, Richard; Johnson, Kendall L., compilers. Proceedings--symposium on the biology of Atriplex and related chenopods; 1983 May 2-6; Provo, UT. General Technical Report INT-172. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 309 p.

Section 1. Distribution, Systematics, and Genetics

DISTRIBUTION, SYSTEMATICS, AND EVOLUTION OF CHENOPODIACEAE: AN OVERVIEW

E. Durant McArthur and Stewart C. Sanderson

ABSTRACT: The moderately sized (100 genera, 1,200-1,500 species) chenopod family is widely distributed. Its plants are quite common in saline and alkaline areas. In some of those areas, especially in south-central Asia, southern Australia, and western North America, woody chenopods dominate large tracts of land. A case is made for herbaceous ancestry of the family. Chenopods have x=9 chromosomes with few exceptions, and polyploidy is common. The family has several adaptations for stressful environments. Ample genetic variation is available for use in manipulation and selection of plants.

INTRODUCTION

Among the families of flowering plants, the chenopod family is moderately sized with some 100 genera and 1,200-1,500 species (Cronquist 1981). For comparative purposes, two familiar families of similar size are Rosaceae (100; 2,000) and Ericaceae (70; 1,900). The largest families of flowering plants, Asteraceae (950; 20,000), Poaceae (700; 7,000), Fabaceae (600; 12,000) are on the order of 10 times as large as Chenopodiaceae (Bailey Hortorium Staff 1976). Nevertheless, the family is very important in terms of the land it occupies in the American West (Blauer and others 1976) and worldwide (Goodall 1982; West 1983). Chenopod plants, especially shrubs, are the only form of plant life found in some wet and dry saline or alkaline situations. In some areas, chenopods form, either singly or in association with other plant species, very large communities. As an example, a single population of the black saxaul tree (*Haloxylon ammodendron*) on the Chu River east of the Aral Sea covers approximately 1,500,000 acres (600,000 ha) (Goodall 1982). There are vast acreages of chenopod shrublands on several continents. Shrubs make a substantial contribution to Chenopodiaceae as do annual and perennial forbs. In addition, there are a few chenopod trees (Benson 1979; Cronquist 1981; Walter and Box 1983).

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This review is intended to give some insights into the family--its genetic relationships, evolution, distribution, importance to man and the landscape, and other facets that, we hope, will engender appreciation of the family.

Chenopod Characteristics

Chenopodiaceae is one of 11 families in the order Caryophyllales or Chenopodiales (Centrospermae) (table 1). These are relatively advanced plants (Takhtajan 1980) characterized by "central seeded" position of ovary placentation, coiled or curved embryos, anomalous secondary thickening of stems and roots, succulent forms, P-type sieve element

Table 1.--The families of Caryophyllales or Chenopodiales with examples.[1]

Families	Example genera
Aizoaceae	*Mesembryanthemum* (icicle plant)
Amaranthaceae	*Amaranthus* (amaranth, redroot)
Basellaceae	*Ullucus*
Cactaceae	*Carnegiea* (saguaro), *Opuntia* (prickly pear)
Chenopodiaceae	*Atriplex* (orache, saltbush), *Beta* (beet), *Chenopodium* (goosefoot), *Spinaca* (spinach)
Didieraceae	*Diderea*
Nyctaginaceae	*Mirabilis* (four-o'clock)
Phytoloccaceae	*Phytolacca* (pokeweed)
Portulaceae	*Portulaca* (purslane)
Caryophyllaceae	*Silene* (campion, pink), *Stellaria* (chickweed)
Molluginaceae	*Mollugo*

[1]From Willis and Airy-Shaw 1973; Mabry 1980. Sometimes Caryophyllales and Chenopodiales are used synonymously. When the orders are considered separately, the last two families are placed in Caryophyllales and the first nine in Chenopodiales. A traditional name for the group has been Centrospermae.

plastids, similar pollen morphology, and betalain pigments (Behnke 1976; Eckardt 1976; Cronquist 1981). The chenopod family itself shares many traits with its relatives--the other centrospermous families (tables 1, 2). The family has been divided into two (Blackwell 1977) or three subfamilies (Williams and Ford-Lloyd 1974) based on embryo, endosperm, and flower and fruit characteristics.

Table 2.--Characteristics of the family Chenopodiaceae.[1]

Shared with order	Family characteristics
"Central-seeded" ovary placentation	Leaves simple, often reduced to scales, usually alternate
Coiled or curved embryos	
Anomalous secondary thickening of stems and roots	Flowers perfect, or less often, unisexual, inconspicuous and apetalous
Succulence	Ovary superior (Beta= half inferior)
Betalain pigments	Fruit a utricle
Pollen morphology	

[1]Drawn from Headstrom 1978; Benson 1979; Cronquist 1981; Goodall 1982.

The family includes familiar vegetables (beet, spinach) and has or has had many other interesting uses (table 3). Shishkin (1936) emphasized the importance of chenopods: "Chenopodiaceae are more particularly associated with central Asia, where they are of considerable economic importance in desert and semi-desert areas. . . . they have no equals as pasture and forage plants and as the exclusive source of desert fuel." Similar statements could be made about chenopods in other areas although the area Shishkin describes may be the most diverse chenopod area (see Origin and Evolution section).

Some chenopods are poisonous to livestock because of oxalic acid content or accumulation of selenium (Kingsbury 1964; Davis 1972; Williams 1979). Other species cause allergies and other health problems for man (Lewis and Elvin-Lewis 1977).

GENERAL DISTRIBUTION

Plants of the family are most common in temperate climates, but the family is cosmopolitan. Eastern, Western, Northern, and Southern hemispheres all have a good representation. Chenopod plants are particularly common in (1) waste places--there are many chenopod weeds, (2) temperate saltmarshes and seaside locations, and (3) desert and semidesert areas. They are often halophytes (Cronquist 1981; Goodall 1982).

ORIGIN AND EVOLUTION

Muller (1970, cited in Raven and Axelrod 1974) suggested that the order Chenopodiales (Caryophyllales) commenced its main differentiation by Paleocene-Eocene time (ca. 55 million years ago). At that time, few angiosperm groups were differentiated. The group is old and our insight into its past is limited. Nevertheless, Raven and Axelrod (1974) were confident enough to state that "it is clear that the Chenopodiales differentiated in West Gondwanaland when Africa and South America were in closer contact." Chenopodiaceae and its near relative Amaranthaceae are now so widespread it is difficult to suggest where these families underwent their early differentiation. However, Ehrendorfer (1976) hypothesized that ancestors of Centrospermae (Chenopodiales) were plants of open, warm, dry, windy habitats with mineral soils. And Stebbins (1974) suggested that the family arose in brackish or saline habitats either along the seashore or in alkaline depressions in desert regions. Once the adaptations for these habitats were firmly established, evolutionary lines could diversify and occupy even more challenging soil types.

If, in fact, the chenopods began in Gondwanaland in the differentiating Chenopodiales matrix, they apparently became established--perhaps with several already differentiated lines--on different continents. Several evolutionarily active hotspots developed, e. g. south-central Asia, Australia, western North America. These areas were not necessarily in evolutionary concert with one another nor were the same taxa evolutionarily active in the different areas.

Herbaceous Ancestry

The ancestral chenopods were probably herbaceous. Most systemists now believe that primitive flowering plants were woody (Stebbins 1974; Takhtajan 1980; Cronquist 1981). In the case of the chenopods, however, the woody plants are probably secondarily woody (Stebbins 1974). Reasons to support the case for an herbaceous ancestry for the woody chenopods include: (1) anomalous secondary thickening of woody stems and roots (Stebbins 1974); (2) C_4 photosynthesis in many shrubs, but only a few herbs (Osmond and others 1980); and (3) more complicated, derived, sexual systems in several of the shrubs (McArthur 1977; Parr-Smith and Calder 1979; McArthur and Freeman 1982).

Data extracted from the Flora of the U.S.S.R. (Shishkin 1936) give further support to the herbaceous ancestry hypothesis. This data base should be useful because the 51 genera and 341 species listed in this flora account for about 50 percent of all chenopod genera, about 30 percent of the species of those genera, and about 25 percent of all chenopod species worldwide. If data for contiguous areas to the south were available, the point would be even more impressive. The Soviet ecologist Keller (1927) suggested that the area around Tashkent in south-central Asia was a vast outdoor laboratory for evolution of desert flora.

Table 3.--Uses for chenopods.[1]

Use	Plants
Animal feed	Mangel wurzel (Beta vulgaris), saltbushes (Atriplex spp.), winterfat (Ceratoides spp.), and others
Anthelmintic	American wormseed (Chenopodium anthelminticum)
Antihypotensive	Arthophytum spp.
Antitumor agents	Bassia spp. and Rhagodia spp.
Birdseed	Red goosefoot (Chenopodium rubrum)
Fuel[2]	Shrubby spp. (Atriplex, Haloxylon, Kochia, Salsola, etc.)
Fishbait	Sea blite (Suaeda maritima)
Grain	Quinoa (Chenopodium quinoa), and others
Herbal medicine	Goosefoots (Chenopodium spp.), oraches (Atriplex spp.), winterfat (Ceratoides lanata), sea purslane (A. portuloides), and others
Ornamental	Fire plant (Kochia scoparia)
Soap and glassmaking[3]	Glasswort (Salicornia and Salsola spp.)
Stabilizing mineral soil	Several genera including Atriplex, Camphorosoma, and Kochia
Vegetables	Beet root (Beta vulgaris), Swiss chard (Beta vulgaris), spinach (Spinaca oleracea), and pot herbs (Atriplex spp., Chenopodium spp., Sarcobatus spp., and others)

[1]Compiled from Grieve 1974; Bailey Hortorium Staff 1976; Simmonds 1976; Lewis and Elvin-Lewis 1977; Headstrom 1978.
[2]Especially in North Africa and south-central and southwestern Asia.
[3]These uses are mentioned in the Bible.

Petrov (1976) lists communities, for example, of 26 perennial plants, mostly shrubs, of which 14 are chenopods in addition to annual saltworts of the genera Salsola, Halogeton, and Suaeda. Of the 341 species listed by Shishkin, 76 percent are herbaceous (mostly annual), 23 percent are shrubs or subshrubs, and 1 percent is arborescent. Table 4 summarizes the importance of Chenopodiaceae in the south-central part of the Soviet Union and by extension to neighboring countries--but see also West 1983.

Centers of Diversity

Chenopodiaceae has wide distribution, but a few areas on a global scale are preeminent in terms of species diversity and dominance. These are south-central Asia, southern Australia, western North America, and to a lesser extent western South America and the Mediterranean Basin.

South-central Asia.--This center of diversity is larger than any other, both in terms of number of species (table 4) and in area of land occupied by chenopod species (Goodall 1982; West 1983). Even though herbaceous plants are more numerous in the number of species, the woody forms are the landscape dominants. In this area, two Haloxylon

Table 4.--Chenopod genera of the U.S.S.R.[1]

Genera with greater than 10 species	Number of species			Other genera of interest	Number of species		
	U.S.S.R.		World		U.S.S.R.		World
	Total	Shrubs			Total	Shrubs	
Salsola	68	[2]26	120	Kochia	8	1	45
Corispermum	34	0	55	Beta	5	0	13
Atriplex	33	3	250	Camphorosoma	4	2	10
Chenopodium	30	0	250	Halogeton	3	0	4
Suaeda	27	3	100	Haloxylon	3	[2]3	5
Anabasis	23	22	30	Ceratoides	2	2	7
Halimocnemis	11	0	12	Spinaca	2	0	3
Petrosimonia	11	0	11				

[1]Extracted from Shishkin 1936; Willis and Airy-Shaw 1973.
[2]Includes two trees.

Figure 1.-- Distribution of saxaul trees (Haloxylon) in south-central Asia (from Petrov 1976).

and two Salsola species reach a tree stature of 20 feet (6.1 m) or more in height (Shishkin 1936; Petrov 1976). The areas occupied by saxaul trees (Haloxylon) are illustrated in figure 1. Collectively, H. ammodendron and H. persicum extend 85° longitudinally and 25° latitudinally. As we pointed out earlier (see Chenopod Characteristics), chenopods are valuable fodder and fuel plants in this area (Shiskin 1936; Petrov 1976).

Southern Australia.--Another area for chenopod diversity and differentiation is Australia where there are 23 chenopod genera of which 20 include endemic species (table 5)--sixteen of the genera are endemic. In all, Australia has 206 chenopod species of which 192 are endemic. The chenopod genera occurring in Australia have a worldwide total of about 970 species (Burbridge 1963; Willis and Airy-Shaw 1973). Many of the Australian species are shrubby. Goodall (1982) maintained that the chenopod flora of Australia, like the landform on which it occurs, is mostly old and relatively stable. See Barlow (1981), however, for an excellent discussion detailing diverse evidence and viewpoints for younger and older floral components and floras. The most common dominants are Atriplex vesicaria, A. nummularia, A. rhagodiodies, Maireana sedifolia, M. pyramidata, M. aphylla, M. astrotricha, Rhagodia spinescens, and R. nutans--that is, saltbushes (Atriplex and Rhagodia) and bluebushes (Maireana) (Oxley 1979). Chenopods, especially the perennials, are much more common in arid southern and central Australia than in the north. One exception is northern bluebush (Chenopodium auricomum), which extends well into Queensland and the Northern Territory (Oxley 1979).

Although the chenopod shrublands are much used by domestic animals in Australia as elsewhere, some Australian range managers view them as less valuable than the ephemerals that replace them as a result of heavy browsing (Wilson 1969; Milthorpe 1970; Wilson and Tupper 1982). The ephemerals on some Australian rangelands are more palatable to sheep and just as nutritious as the shrubs. The chenopod shrubs, however, are extremely valuable in times of drought when the ephemerals are not present. In Australia, as in North America, shrubs and shrub management evoke arguments among land stewards as to their relative merits. Chenopod

shrublands have been severely modified in some Australian areas by livestock use (Jones 1970; Graetz and Howes 1979) as they also have been in the Middle East (Sankary 1976) and in western North America (Holmgren and Hutchings 1972; West 1983; Blaisdell and Holmgren[1]).

Western North America.--The third and final area of chenopod diversity we will examine is North America. This area has a rich chenopod flora that apparently has recent and current evolutionary activity, especially among the shrubby Atriplexes (Stutz 1978, these proceedings). However, North America is not as taxonomically rich as southern Australia and south-central Asia (table 5). Stutz (1978) has made a case for recent, rapid evolution in shrubby Atriplex in western North America. Axelrod (1950; 1979), Wolfe (1975, 1978), and others have shown that the habitats available to woody chenopods were not available or were much smaller until recent times.

Table 5.--Chenopod endemism.[1]

Area	Number of genera: Total	Number of genera: Endemic	Percent
U.S.S.R.	51	12	[2]24
Australia	23	16	70
North America	23	7	30
Utah	17	4	[3]24

[1]Data sources: Standley 1916; Shishkin 1936; Burbridge 1963; Welsh and others 1981. Follows taxonomy of Willis and Airy-Shaw 1973.
[2]Low as a measure of south-central Asia because many generic distributions cross southern border.
[3]Includes North American endemics.

An examination of the worldwide distribution of Atriplex confirms high diversity for the genus in North America. The preeminent position of Atriplex in North America can be seen in table 6. Three genera (Grayia, Sarcobatus, and Zuckia) are endemic. The other five (Allenrolfea, Atriplex, Ceratoides, Kochia, and Suaeda) have endemic species, but have richer areas of differentiation elsewhere. Atriplex is well differentiated in North America as well as other locations. There are 18 North American genera that include herbaceous species; five genera (Bassia, Beta, Axyris, Salsola, Spinaca) are naturalized and three genera (Aphanisma, Cycloloma, Meiomera) are endemic (Standley 1916; Willis and Airy-Shaw 1973). Osmond and others (1980) divided the world into nine Atriplex species distribution areas. In terms of Atriplex species endemism, South America was highest with 86 percent of its 73 species endemic; North American next with 78 percent of its 59 species; and then Australia with 68 percent of its 59 species. None of the other areas exceeded 42 species or 40 percent endemism. We point out, however, that the Osmond and others analysis divided south-central Asia into three separate areas which are not necessarily natural. The analysis did not include undescribed Atriplex taxa in North America that Stutz (1978, these proceedings) intends to formally describe. Data from Atriplex DNA homologies (Belford and Thompson 1981a, 1981b) suggest that the major period for separation of Atriplex into phyletic lines occurred 30-35 million years ago, at the time of C_3 and C_4 photosynthetic pathway separation in the genus. Differentiation within the lines has apparently taken place at different rates in different places, for example, relatively less over a longer time in

Table 6.--Distribution and growth habits of chenopod species with affinities to North American chenopod shrubs.[1]

Genus of North American shrub	Number of species: Shrubs, western USA	Number of species: All forms, world	Extra North American distribution	Nonshrub growth habits
Allenrolfea	1	3	Northern hemisphere, South America	--
Atriplex	18	250	Worldwide	Herbs
Ceratoides	1	7	Eurasia	--
Grayia	2	2	--	--
Kochia	1	45	Eurasia	Herbs
Sarcobatus	2	2	--	--
Suaeda	3	50	Worldwide	Herbs
Zuckia	1	1	--	--

[1]Compiled from Standley 1916; Willis and Airy-Shaw 1973; McArthur 1984.

[1]Blaisdell, J. P.; Holmgren, R. C. Managing Intermountain rangelands--salt-desert shrub ranges. Gen. Tech. Rep. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. In press.

Australia (Barlow 1981) as compared to more recent differentiation in North America (Stutz 1978). All Australian Atriplex is apparently C_4 whereas other Atriplex-occurring areas include both C_3 and C_4 species (Osmond and others 1980).

Chenopod Chromosomes

The family Chenopodiaceae is remarkably stable in chromosome base numbers--predominantly x=9 with only rare aneuploidy (table 7; Raven 1975). However, polyploidy is quite common (table 7).

Table 7.--Chromosome number patterns in Chenopodiaceae.[1]

Chromosome numbers	
Base number	Number of genera
6	1
8,9	1
9	43
12	2

Polyploid chromosome number patterns	
Pattern	Number of genera
2x	26
2x-4x	6
2x-6x	1
2x-6x, 12x	1
2x-8x	2
2x-8x, 12x	1
2x-12x	1
4x	7
4x-6x	1
4x-8x	1

Number of species[2]					
2x	4x	6x	8x	10x	12x
257	114	34	11	3	2

[1]Data compiled from Ornduff (1967); Federov (1969); Moore (1973, 1974, 1977); Nobs (1980); Goldblatt (1981); McArthur and Sanderson (unpublished data on file at the Shrub Sciences Laboratory, Provo, Utah).

[2]Counts the species, e.g., Atriplex canescens, A. confertifolia, A. vesicaria, Kochia prostrata, etc., that are polyploid in each ploidy level at which they are known.

Diploids (2x) and tetraploids (4x) are common, but some taxa are known up to dodecaploid (12x). There are polyploid taxa at both the generic and specific levels. For example, the North American species Atriplex canescens (2x-12x) (Stutz and Sanderson 1979) and A. confertifolia (2x-10x) (Stutz and Sanderson 1983), the Eurasian Kochia prostrata (2x-6x) (Herbel and others 1981; McArthur and Sanderson[2]), and the Australian A. vesicaria (2x-6x) are continent-bridging, vigorous polyploid species complexes.

Chenopod chromosomes are small. Atriplex chromosomes, for example, are only about 1 μm long (McArthur 1977). The average Atriplex genome is only 12 percent the size of a pea (Pisum) genome although the Atriplex genome includes two additional chromosomes (Belford and Thompson 1981a). The spinach genome is about one-third larger than that of Atriplex, but has a third less chromosomes. Chromosomes of shrubby Atriplexes are difficult to karyotype because of their small, rather uniform nature (Stutz and others 1975; McArthur 1977; Nobs 1980; McArthur and Sanderson[2]). Gustaffson (1972, 1974) has used paracentric inversions to unravel genetic relationships among populations of the Scandinavian herbs Atriplex longipes and A. triangularis.

BREEDING SYSTEMS

Most chenopods are wind pollinated with small inconspicuous flowers. Flowers may be perfect (bisexual) or unisexual--the plants then monoecious or dioecious (Benson 1979; Cronquist 1981). The most advanced plants (see Origin and Evolution), the C_4 shrubs, are those with derived sexual systems. Derived, we think, by being specialists to take better advantage of scarce resources in a stressful environment. The C_4 shrubs are basically dioecius or subdioecious. An example is the apparent trioecious system of tetraploid Atriplex canescens (McArthur 1977; McArthur and Freeman 1982). In that system there are not only constant male and female plants, but also a labile group that may be male, female, or monoecious depending in part on environmental stress. These labile plants, we believe, react to environmental stress (winter cold, drought, crowding) by moving away from female function in physiologically stressful times. Some other genera, notably the C_3 shrubs Sarcobatus and Grayia, are monoecious but vary their particular investment in male and female function from dry to mesic sites (Sarcobatus vermiculatus--Freeman and others 1981) and from year to year (Grayia brandegei--McArthur and Blauer[3]). We believe these monoecious systems are more primitive than the subdioecious ones, but that the two kinds of systems are corollary to one another. And, that both kinds of systems have evolved to allow their species to more efficiently occupy stressful, heterogenous, patchy environments.

ADAPTATION TO STRESSFUL HABITATS

Chenopod plants have undergone several adaptive modifications to enable them to survive in difficult environments (Goodin 1975; Goodall 1982):

[2]McArthur, E. D.; Sanderson, S. C. Data on file at the Shrub Sciences Laboratory, Provo, Utah; 1983.

[3]McArthur, E. D.; Blauer, A. C. Data on file at the Shrub Sciences Laboratory, Provo, Utah; 1983.

C_4 and CAM photosynthesis[4]
Seed dormancy mechanisms
Reductions in leaf surface areas
Hairs covering epidermis
Xeromorphy (thick cuticle and recessed stomata)
Deep root systems
Ephemeral roots after rains
Internal water potential capability
Tolerance to salinity

That they survive, even thrive, in some of the most inhospitable habitats is well known. Atriplex confertifolia is photosynthetically active from 23° F (5° C) to 122° F (50° C)--the widest range known for any plant (Caldwell 1972).

Sodium, a poison to most plants, is a stimulant for many chenopods and even an essential nutrient for some (Kleinkopf and others 1975; Blauer and others 1976; Goodall 1982). Flowers (1934), in a classic study on the vegetation of the Great Salt Lake region, showed the successional order for plants from the lake shore out (a saline gradient halosere) to be: Salicornia rubra → S. utahensis → Suaeda erecta → Allenrolfea occidentalis → Distichlis spicata → small Poaceae and Brassicaceae herbs → Atriplex spp. All of these plants except Distichlis and the herbs are chenopods. Branson's group (Branson and others 1967, 1976; Miller and others 1982) has studied the tolerance to internal moisture and soil moisture stress for several areas and species in the salt-desert shrub type of the Western United States. Shrubby chenopods were able to handle stress better than any other species they studied.

GENETIC VARIATION

Each taxon has different amounts of variation, a point made in the Evolution and Origin section. Nevertheless, in general, most species have substantial genetic variation. Atriplex canescens, which has received considerable study, harbors abundant variation (table 8). Some other wide-ranging species complexes, for example, Kochia prostrata, are in all likelihood equally variable. Goodman (1973) documented ecotypic variation for several chenopod shrubs.

The variation in western shrubs like Atriplex canescens offers ample opportunity for use of natural ecotypes (McArthur and others 1983) or selected material (McArthur and others 1984) for use in revegetation efforts. There is great opportunity to use and enhance valuable resources--the chenopod shrubs.

[4]The C_4 and CAM photosynthesis systems are thought to be more efficient in hot climates than the conventional C_3 system. However this has not been practically demonstrated. For example, Ceratoides lanata (C_3) and Atriplex confertifolia (C_4) are equally efficient on an annual basis in Curlew Valley, Utah. Ceratoides is more efficient in the spring, but Atriplex is more efficient in summer (Caldwell 1972).

Table 8.--Characteristics of Atriplex canescens which show variability between sites or accessions.[1]

Characteristic	References
Soil salinity	Northington and Goodin 1975; Welch 1978; Richardson and McKell 1980.
Ash content	Welch 1978
Crude protein	Gamrath 1972; Welch 1978; Welch and Monsen 1981
Stem rooting	Van Epps and McKell 1978; Richardson and others 1979.
Palatability	Van Epps, unpublished[2].
Winter hardiness	Van Epps 1975; Kay and others 1977.
Seed production, fill, and germination	Plummer and others 1966; Springfield 1970; Gamrath 1972; Stutz and others 1975; Gerard 1978.
Sex expression	Stutz and others 1975; McArthur 1977; McArthur and Freeman 1982.
Chromosome number	Stutz and others 1975; Stutz and Sanderson 1979.
Growth rate and form	Plummer and others 1966; Stutz and others 1975
Allozymes	McArthur and others unpublished[3]

[1]Adapted and expanded from McArthur and others, 1983.
[2]Data on file, Snow Field Station, Ephraim, Utah.
[3]McArthur, E. D.; Sanderson, S. C.; Freeman, D. C. Isozymes of an autopolyploid shrub, Atriplex canescens (Chenopodiaceae), manuscript in review.

The family through its wide distribution and ample differentiation, has been and will continue to be useful in a multitude of ways (table 3). Its forbs, shrubs, even trees, are often found in inhospitable environments where they usually enhance life of other organisms including mankind. We must remember, however, that some species can be weedy or poisonous.

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PUBLICATIONS CITED

Axelrod, D. I. Contributions to paleontology. VI. Evolution of desert vegetation in North America. Publ. 590. Washington, DC: Carnegie Institute of Washington; 1950: 215-306.

Axelrod, D. I. Desert vegetation, its age and origin. In: Goodin, J. R.; Northington, D. K., eds. Arid land plant resources. Lubbock, TX: International Center for Arid and Semi-arid Land Studies, Texas Tech. University; 1979: 1-72.

Bailey Hortorium Staff. L. H. Hortus III. New York: MacMillan; 1976. 1290 p.

Barlow, B. A. The Australian flora: its origin and evolution. In: Flora of Australia. Vol. 1, introduction. Canberra: Australian Government Publishing Service; 1981: 25-75.

Behnke, H. D. Ultrastructure of sieve-element plastids in Caryophyllales (Centrospermae), evidence for the delimitation and classification of the order. Plant Syst. Evol. 126: 31-54; 1976.

Belford, H. S.; Thompson, W. F. Single copy DNA homologies in *Atriplex*. I. Cross reactivity estimates and the role of deletions in genome evolution. Heredity. 46: 91-108; 1981a.

Belford, H. S.; Thompson, W. F. Single copy DNA homologies in *Atriplex*. II. Hybrid thermal stabilities and molecular phylogeny. Heredity. 46: 109-122; 1981b.

Benson, L. Plant classification. 2d ed. Lexington, MA: D. C. Heath and Co.; 1979. 901 p.

Blackwell, W. H., Jr. Subfamilies of Chenopodiaceae. Taxon. 26: 395-397; 1977.

Blauer, A. C.; Plummer, A. P.; McArthur, E D.; Stevens, R.; Giunta, B. C. Characteristics and hybridization of important Intermountain shrubs. II. Chenopod family. Res. Pap. INT-177. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1976.42 p.

Branson, F. A.; Miller, R. F., McQueen, I. S. Geographic distribution and factors affecting the distribution of salt desert shrubs in the United States. J. Range Manage. 20: 287-296; 1967.

Branson, F. A.; Miller, R. F., McQueen, I. S. Moisture relationships in 12 northern desert shrub communities near Grand Junction, Colorado. Ecology. 57: 1107-1124; 1976.

Burbridge, N. T. Dictionary of Australian plant genera. Sydney: Angus Robertson Ltd.; 1963. 345 p.

Caldwell, M. M. Gas exchange of shrubs. In: McKell, C. M.; Blaisdell, J. P.; Goodin, J. R., eds. Wildland shrubs--their biology and utilization. Gen. Tech. Rep. INT-1. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1972: 260-270.

Cronquist, A. An integrated system of classification of flowering plants. New York: Columbia University Press; 1981. 1262 p.

Davis, A. M. Selenium accumulation in a collection of *Atriplex* species. Agron. J. 64: 823-824; 1972.

Eckhardt, T. Classical morphological features of Centrospermous families. Plant Syst. Evol. 126: 5-25; 1976.

Ehrendorfer, F. Closing remarks: systematics and evolution of Centrospermous families. Plant Syst. Evol. 126: 99-105; 1976.

Federov, A. A. Chromosome numbers of flowering plants. Leningrad: Izdateyvo Nauk; 1969. 928 p.

Flowers, S. Vegetation of the Great Salt Lake region. Bot. Gaz. 95: 353-418; 1934.

Freeman, D. C.; McArthur, E. D.; Harper, K. T.; Blauer, A. C. Influence of environment on the floral sex ratio of monoecious plants Evolution. 35: 194-197; 1981.

Gamrath, W. G. The relationship of plant morphology and seed processing to utricle fill and germination of fourwing saltbush (*Atriplex canescens* [Pursh] Nutt.) seed. Bozeman, MT: Montana State University, 1972. 48 p. Thesis.

Gates, D. H.; Stoddart, L. A.; Cook, C. W. Soil as a factor influencing plant distribution on salt-deserts of Utah. Ecol. Monogr. 26: 155-175; 1956.

Gerard, J. B. Factors affecting fruit fill and seed germination of fourwing saltbush (*Atriplex canescens* [Pursh] Nutt.). In: Hyder, D. N. ed. Proceedings, first international rangeland congress; 1978, August 14-18; Denver, CO: Denver, CO: Society for Range Management, 1978: 403-405.

Goldblatt, P., ed. Index to plant chromosome numbers 1975-1978. Monographs in systematic botany from the Missouri Botanical Garden No. 5. St. Louis, MO: Missouri Botanical Garden; 1981. 553 p.

Goodall, D. W. Chenopod shrubland communities--a global perspective. Internatl. J. Ecol. and Environ. Sci. 9: 85-99; 1982.

Goodin, J. R. Salinity relations in shrubs. In: Stutz, H. C., ed. Proceedings, symposium and workshop on the occasion of the dedication of the U.S. Forest Service Shrub Sciences Laboratory. Provo, UT: Brigham Young University; 1975: 1-31.

Goodman, P. J. Physiological and ecotypic adaptations of plants to salt desert conditions in Utah. J. Ecol. 61: 473-494; 1973.

Graetz, R. D.; Howes, K. M. W., eds. Studies of the Australian arid zone. IV. Chenopod shrublands. Melbourne: Commonwealth Scientific and Industrial Research Organization; 1979. 196 p.

Grieve, M. A modern herbal. New York: Hafner Press; 1974. 916 p. (Reprint of 1931 edition.)

Gustaffsson, M. Distribution and effects of paracentric inversions in populations of Atriplex longipes. Hereditas. 71: 173-194; 1972.

Gustaffsson, M. Evolutionary trends in the Atriplex triangularis group of Scandinavia. III. The effects of population size and introgression on chromosomal differentiation. Bot. Not. 127: 125-148; 1974.

Headstrom, R. The families of flowering plants. New York: A. S. Barnes Co.; 1978. 427 p.

Herbel, C. H.; Barnes, R. F.; Heady, H. F.; Purdy, L. N. Range research in the Soviet Union. Rangelands. 3: 61-63; 1981.

Holmgren, R. C.; Hutchings, S. S. Salt desert shrub response to grazing use. In: McKell, C. M.; Blaisdell, J. P.; Goodin, J. R., eds. Wildland shrubs--their biology and utilization. Gen. Tech. Rep. INT-1. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1972: 153-164.

Jones, R., ed. The biology of Atriplex. Canberra: Commonwealth Scientific and Industrial Research Organization; 1970. 128 p.

Kay, B. L.; Brown, C. R.; Graves, W. L. Mohave Valley revegetation notes. No. 17. Fourwing saltbush. Davis, CA: University of California; 1927. 12 p.

Keller, B. A. Distribution of vegetation on the plains of European Russia. J. Ecol. 15: 189-233; 1972.

Kingsbury, J. M. Poisonous plants of the United States and Canada. Englewood Cliffs, NJ: Prentice-Hall; 1964. 626 p.

Kleinkopf, G. E.; Wallace, A.; Cha, J. W. Sodium relations in desert plants. IV. Some physiological responses of Atriplex confertifolia to different levels of sodium chloride. Soil Sci. 120: 45-48; 1975.

Lewis, W. H.; Elvin-Lewis, M. P. F. Medical botany, plants affecting man's health. New York: John Wiley and Sons; 1977. 515 p.

Mabry, J. J. Betalains. In: Bell, E. A.; Charlwood, B. V., eds. Secondary plant products. Berlin: Springer-Verlag; 1980: 513-533.

McArthur, E. D. Environmentally induced changes of sex expression in Atriplex canescens. Heredity. 38: 97-103; 1977.

McArthur, E. D. Natural diversity of western range shrubs. In: Cooley, J. L.; Cooley, J. H., eds. Natural diversity in forest ecosystems. Athens, GA: Institute of Ecology, University of Georgia; 1984: 193-209.

McArthur, E. D.; Freeman, D. C. Sex expression in Atriplex canescens: genetics and environment. Bot. Gaz. 143: 476-482; 1982.

McArthur, E. D.; Stevens, R.; Blauer, A. C. Growth performance comparisons among 18 accessions of fourwing saltbush (Atriplex canescens) at two sites in central Utah. J. Range Manage. 36: 78-81; 1983.

McArthur, E. D.; Stranathan, S. E.; Noller, G. L. 'Rincon' fourwing saltbush--proven for better forage and reclamation. Rangelands. 6: 62-64; 1984.

Miller, R. F.; Branson, F. A.; McQueen, I. S.; Snyder, C. T. Water relations in soils as related to plant communities in Ruby Valley, Nevada. J. Range Manage. 34: 462-468; 1982.

Milthorpe, F. L. Atriplex--Atlantean or Atrabilarian? In: Jones, R., ed. The biology of Atriplex. Canberra: Commonwealth Scientific and Industrial Research Organization; 1970: 123-125.

Moore, R. J., ed. Index to plant chromosome numbers 1967-1971. Regnum vegtabile, vol. 90. Utrecht, Netherlands: International Bureau for Plant Taxonomy and Nomenclature; 1973. 539 p.

Moore, R. J., ed. Index to plant chromosome numbers 1972. Regnum vegtabile, vol. 91. Utrecht, Netherlands: International Bureau for Plant Taxonomy and Nomenclature; 1974. 108 p.

Moore, R. J., ed. Index to plant chromosome numbers 1973-1974. Regnum vegtabile, vol. 96. Utrecht, Netherlands: International Bureau for Plant Taxonomy and Nomenclature; 1977. 257 p.

Nobs, M. A. Chromosome numbers in Australian species of Atriplex. Carnegie Inst. Yearbook. 79: 164-169; 1980.

Northington, D. K.; Goodin, J. R. Variability in natural populations of Atriplex canescens. In: Stutz, H. C., ed. Proceedings, symposium and workshop on the occasion of the dedication of the U.S. Forest Service Shrub Sciences Laboratory. Provo, UT: Brigham Young University; 1975: 149.

Ornduff, R., ed. Index to plant chromosome numbers 1956. Regnum vegtabile, vol. 50. Utrecht, Netherlands: International Bureau for Plant Taxonomy and Nomenclature; 1967. 128 p.

Osmond, C. B.; Bjorkman, O.; Anderson, D. J. Physiological processes in plant ecology: toward a synthesis with Atriplex. Berlin: Springer-Verlag; 1980. 468 p.

Oxley, R. E. the perennial chenopod pasturelands of Australia. In: Graetz, R. D.; Howes, K. M. W., eds. Studies of the Australian arid zone. IV. Chenopod shrublands. Melbourne: Commonwealth Scientific and Industrial Research Organization; 1979: 1-4.

Parr-Smith, G. A.; Calder, D. M. Atriplex vesicaria Heward ex. Benth. and related species: taxonomy and variation. In: Graetz, R. D.; Howes, K. M. W., eds. Studies of the Australian arid zone. IV. Chenopod shrublands. Melbourne: Commonwealth Scientific and Industrial Research Organization; 1979: 17-28.

Petrov, M. P. Deserts of the world. New York: John Wiley and Sons; 1976. 447 p. (Pustyni Zemnogoshara. Leningrad: Izdatel'stud Nauk; 1973. Transl. by Israel Program for Scientific Translations.)

Plummer, A. P.; Monsen, S. B.; Christensen, D. R. Fourwing saltbush, a shrub for future game ranges. Publ. 66-4. Salt Lake City, UT: Utah Department Fish and Game; 1966. 183 p.

Raven, P. H. The bases of angiosperm phylogeny: cytology. Ann. Missouri Bot. Gard. 62: 724-764; 1975.

Raven, P. H.; Axelrod, D. I. Angiosperm biogeography and past continental movements. Ann. Missouri Bot. Gard. 61: 539-763; 1974.

Richardson, S. G.; Barker, J. R.; Van Epps, G. A. Factors affecting rooting stem cuttings of salt desert shrubs. J. Range Manage. 32: 280-283; 1979.

Richardson, S. G.; McKell, C. M. Salt tolerance of two saltbush species grown in processed oil shale. J. Range Manage. 33: 460-463; 1980.

Sankary, M. N. The autecology and dynamics of Atriplex leucoclada Bois, in the Syrian Badia and Hamada. Res. J. Alleppo Univ. 1: 43-47; 1976.

Shishkin, B. K., ed. Flora of the U.S.S.R. Volume VI. Centrospermae. Publ. TT 69-55053. Washington, DC: U.S. Department of Commerce; 1970. 731 p. (Transl. by Israel Program for Scientific Translations.)

Simmonds, N. W., ed. Evolution of crop plants. London: Longman Group; 1976. 339 p.

Springfield, H. W. Germination and establishment of fourwing saltbush in the Southwest. Res. Pap. RM-55. Fort Collins. CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1970. 48 p.

Standley, P. C. Chenopodiaceae. North American Flora. 2: 1-93; 1916.

Stebbins, G. L. Flowering plants, evolution above the species level. Cambridge, MA: The Belknap Press of Harvard University Press; 1974. 399 p.

Stutz, H. C. Explosive evolution of perennial Atriplex in Western North America. Great Basin Naturalist Memoirs. 2: 161-168. 1978.

Stutz, H. C.; Melby, J. M.; Livingston, G. K. Evolutionary studies of Atriplex: a relic gigas diploid population of Atriplex canescens. Am. J. Bot. 62: 236-245. 1975.

Stutz, H. C.; Sanderson, S. C. The role of polyploidy in the evolution of Atriplex canescens. In: Goodin, J. R.; Northington, D. K., eds. Arid land plant resources. Lubbock, TX: International Center for Arid and Semi-arid Land Studies, Texas Tech. Univ.; 1979: 615-621.

Stutz, H. C.; Sanderson, S. C. Evolutionary studies in Atriplex: chromosome races of Atriplex confertifolia (shadscale). Am. J. Bot. 70: 1536-1547. 1983.

Takhtajan, A. L. Outline of the classification of flowering plants (Magnoliophyta). Bot. Rev. 46: 225-359; 1980.

Van Epps, G. A. Winter injury to fourwing saltbush. J. Range Manage. 28: 157-159. 1975.

Van Epps, G. A.; McKell, C. M. Major criteria and procedures for selecting and establishing range shrubs as rehabilitators of disturbed lands. In: Hyder, D. N., ed. Proceedings, first international rangeland congress; 1978, August 14-18, Denver, CO. Denver, CO: Society for Range Management; 1978: 352-354.

Walter, H.; Box, E. O. The deserts of central Asia. In: West, N. E., ed. Temperate deserts and semi-deserts. Ecosystems of the world. Vol. 5. Amsterdam: Elsevier Scientific Publ. Co.; 1983: 193-236.

Welch, B. L. Relationship of soil salinity, ash, and crude protein in Atriplex canescens. J. Range Manage. 31: 132-133. 1978.

Welch, B. L.; Monsen, S. B. Winter crude protein differences among accessions of fourwing saltbush grown in a uniform garden. Great Basin Naturalist. 41: 343-346; 1981.

Welsh, S. L.; Atwood, N. D.; Goodrich, S.; Neese, E.; Thorne, K. H.; Albee, B. Preliminary index of Utah vascular plant names. Great Basin Naturalist. 41: 1-108; 1981.

West, N. E., ed. Temperate deserts and semi-deserts. Ecosystems of the world. Vol. 5. Amsterdam: Elsevier Scientific Publ. Co.; 1983. 522 p.

Williams, J. T.; Ford-Lloyd, B. V. The systematics of the Chenopodiaceae. Taxon. 23: 353-354; 1974.

Williams, M. C. Defensive strategy for poisonous introduced plants. Rangelands. 1: 12-13; 1979.

Willis, J. C.; Airy-Shaw, H. K. A dictionary of the flowering plants and ferns. Cambridge, United Kingdom: University Press; 1973. 1245 p.

Wilson, A. D. A review of browse in the nutrition of grazing animals. J. Range Manage. 22: 23-28; 1969.

Wilson, A. D.; Tupper, G. J. Concepts and factors applicable to the measurement of range condition. J. Range Manage. 35: 684-689; 1982.

Wolfe, J. A. Some aspects of plant geography of the northern hemisphere during the late Cretaceous and Tertiary. Ann. Missouri Bot. Gard. 62: 264-279; 1975.

Wolfe, J. A. A paleobotanical interpretation of Tertiary climates in the northern hemisphere. Am. Sci. 66: 694-703; 1978.

In: Tiedemann, Arthur R.; McArthur, E. Durant; Stutz, Howard C.; Stevens, Richard; Johnson, Kendall L., compilers. Proceedings--symposium on the biology of Atriplex and related chenopods; 1983 May 2-6; Provo, UT. General Technical Report INT-172. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 309 p.

ATRIPLEX HYBRIDIZATION IN WESTERN NORTH AMERICA

Howard C. Stutz

ABSTRACT: Interspecific hybridization is unusually common in the genus *Atriplex* in western North America. This stems from numerous contacts of species which were until recently geographically separated and also from selective advantages in habitats made available by the demise of Pleistocene lakes. The rich gene pools which have been provided by this extensive hybridization have resulted in the origin of many new taxa.

INTRODUCTION

In controlled experiments it has been shown that selection against interspecific hybrids results in rapid accumulation of reproductive isolation barriers, whereas selection for hybrids quickly erodes them (Koopman 1950, Wallace 1954, Knight 1956, Kessler 1966). Consequently, if environments are available which enhance the probability of survival of hybrid products, hybridization will expectedly be more common than in areas where hybrids are at a severe disadvantage. This has been amply demonstrated in many groups of plants and animals (e.g. Muller 1952, Ehrman 1965, Grant 1966). Since stable environments ordinarily precipitate well defined species, each of which is superbly and uniquely adapted to specific niches, hybridization in them will expectedly be rare (Epling 1947, Anderson 1948). In disturbed or rapidly changing environments, on the other hand, where opportunities are available for new genotypes, hybridization will expectedly be much more common (Weigand 1935, Epling 1947).

This is graphically illustrated in *Atriplex*. In Australia, where the salt deserts which are now occupied by *Atriplex* and other chenopods have had a relatively long quiescent geological history (Barlow 1981), *Atriplex* hybrids are rare. But in western North America, where there have been extensive, recent, geological disturbances, a rich array of new environmental opportunities has been provided, and hybridization is rampant (Stutz 1978).

The second major contributor to natural hybridization derives, in part, from the first. When species coexist in environments which select *against* hybrids, isolation barriers will ordinarily differ from area to area and from species to species. Because the barriers are established as avenues to prevent hybridization between specific sympatric species they are almost always ineffective when applied to new contacts. Consequently species which are brought together after long periods of isolation will have fewer operative reproductive barriers than species which have been together for long periods of time without advantaged hybrid products (Grant 1966).

ATRIPLEX HYBRIDIZATION IN NORTH AMERICA

Interspecific hybridization in *Atriplex* in western North America is abundant. The dramatic climatic changes which came at the end of the Wisconsin pluvoglacial, causing the demise of old Lake Bonneville and other Pleistocene lakes, provided a myriad of new habitats into which a variety of species could synchronously migrate. Southern species migrated northward, northern species came south, eastern species migrated to the west, and western species to the east. The Great Basin became the "Great Melting Pot." Related species without former contact intermingled and hybridized freely in this new arena. Having no preformed reproductive isolation barriers, having numerous available unoccupied habitats, and acquiring numerous advantages from hybridization, hybrid products were, and still are, unusually common.

The principal *Atriplex* species which have entered this "Basin of Promiscuity" are *A. canescens*, *A. obovata*, *A. polycarpa* and *A. confertifolia* from the south; *A. tridentata*, *A. gardneri*, and *A. falcata* from the north. Some hybrids are very common (e.g. *A. canescens* x *A. tridentata*) (Stutz and others 1979); some hybrid products have become well-established new taxa (e.g. *A. canescens* x *A. gardneri*---*A. aptera*)(Nelson 1902). Many have formed extensive hybrid swarms which, although still too genetically flexible to be considered distinct taxa, contain the genetic wherewithal for producing many new forms; several others are already well established adaptive species awaiting nomenclatural designation.

A. canescens appears to be particularly prone to interspecific hybridization. Some of the best-known and significant hybrids are as follows:

1. *A. canescens* x *A. gardneri* -- *A. aptera* (Nelson 1902).

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These hybrid products are common throughout most of Montana, northeastern Wyoming, and western South Dakota. Each population is genetically unique but they all are well adapted to heavy clay, alkaline soils, particularly on the banks of tributaries of the Missouri River. "Wytana saltbush" is one of the many forms of this remarkable "hybrid species".

2. *A. canescens* x *A. tridentata* has yielded several important new taxa (Stutz and others 1979) including, but not restricted to, the following:

   a. Near Tooele, Tooele Co. Utah, a hexaploid taxa occupies about 100 acres of pasture land. It is well suited to heavy clay soils, is late flowering, and has a few other *tridentata*-like attributes but otherwise is much like the tetraploid *A. canescens* which grows nearby.

   b. Abundant throughout Reese Valley, Lander Co. Nev., is a highly variable product, not yet settled-down to a single adaptive theme. These variables could provide a number of new taxa if appropriate habitats emerge.

   c. Along the shoulders of I-15 between Wendover, Nev. and Delle, Ut. is a new, particularly robust taxa. It has *tridentata*-like fruits but also considerable woodiness and tall stature acquired from *A. canescens*.

3. *A. canescens* x *A. confertifolia* is a rather common hybrid. Introgression has produced several improved forms adapted to harsher sites than *A. canescens* can generally tolerate.

4. *A. canescens* x *A. falcata* appears to be the parentage of *A. bonnevillensis* (Hanson 1962). This hybrid "species" is still genetically highly flexible.

5. *A. canescens* x *A. cuneata* is a very common hybrid in eastern Utah and western Colorado. Introgression is common into both parents but no specific derivative has yet been described.

6. *A. canescens* x *A. polycarpa* has given rise to *A. laciniata*, a well adapted although variable species in the Mohave Desert. It appears to be an allopolyploid but of polyphyletic origins.

7. *A. canescens* x *A. garrettii* has produced *A. navajoensis* (Hanson 1962) in a narrowly endemic region south of Lake Powell, Ariz.

Other common, important *Atriplex* hybrids include:

A. canescens x *A. obovata*
A. confertifolia x *A. cuneata* (*A. neomexicana*)
A. confertifolia x *A. corrugata*
A. confertifolia x *A. obovata*
A. cuneata x *A. corrugata*
A. polycarpa x *A. obovata*
A. polycarpa x *A. linearis*
A. polycarpa x *A. confertifolia*

As a result of this rampant interspecific hybridization, *Atriplex* is among the most genetically rich of all plant genera. It is, many times over, the most genetically variable of all chenopods in western North America. Whereas each of the other chenopod genera contain only one or two species, *Atriplex* consists of more than 20 named species and at least that many more well-defined yet-to-be-named taxa. Hybrid swarms and introgressive products have provided myriads of new genotypes which are, even now, exploring numerous habitats available as a result of dramatic climatic and geological changes in post-Pleistocene geography. Besides the numerous species which have emerged and which are even now emerging in natural settings, the potential for deliberate breeding and selection of varieties suited for specific use on ranges, mine spoils, and other disturbed sites is nearly unlimited.

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PUBLICATIONS CITED

Anderson, E. Hybridization of the habitat. Evolution 2: 1-9;1948.

Barlow, B. A. The Australian flora: its origin and evolution. In: Robertson, R., Flora of Australia. Canberra, Australia: Bureau of Flora and Fauna, Vol. 1; 1981. 200 p.

Ehrman, L. Direct observation of sexual isolation between allopatric and between sympatric strains of the different Drosophila paulistorum races. Evolution 19: 459-64; 1965.

Epling, C. Natural hybridization of Salvia apiana and S. mellifera. Evolution 1: 69-78; 1947.

Grant, V. The selective origin of incompatibility barriers in the plant genus Gilia. Am. Nat. 100: 99-118; 1966.

Hanson, C. A. New species of perennial Atriplex from the western United States. Studies Sys. Bot. 1: 1-4; 1962.

Koopman, K. F. Natural selection for reproductive isolation between Drosophila pseudoobscura and Drosophila persimilis. Evolution 4: 135-145; 1950.

Kessler, S. Selection for and against ethological isolation between Drosophila pseudoobscura and Drosophila persimilis. Evolution 20: 634-645; 1966.

Knight, G. R; Robertson, A.; Waddington, C. H. Selection for sexual isolation within a species. Evolution 10: 14-22; 1956.

Muller, C. H. Ecological control of hybridization in Quercus: A factor in the mechanism of evolution. Evolution 6: 147-61; 1952.

Nelson, A. Contributions to the Rocky Mountain Herbarium, IV. Bot. Gaz. 34: 355-371: 1902.

Stutz, H. C. Explosive evolution of Atriplex in western N. America. In: Intermountain Biogeography, Great Basin Naturalist Memoirs,2: 161-168; 1978.

Stutz, H. C.; Pope, C. L.; Sanderson, S. C. Evolutionary studies of Atriplex: Adaptive products from the natural hybrid 6N A. tridentata x 4N A. canescens. Am. J. Bot. 66: 1181-1193; 1979.

Wallace, B. Genetic divergence of isolated populations of Drosophila melanogaster. Caryology. 6(Supp.): 761-64; 1954.

Wiegand, K. M. A taxonomist's experience with hybrids in the wild. Science 81: 161-6; 1935.

In: Tiedemann, Arthur R.; McArthur, E. Durant; Stutz, Howard C.; Stevens, Richard; Johnson, Kendall L., compilers. Proceedings--symposium on the biology of Atriplex and related chenopods; 1983 May 2-6; Provo, UT. General Technical Report INT-172. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 309 p.

BIG SAGEBRUSH-WINTERFAT AND BIG SAGEBRUSH-NUTTALL SALTBUSH

MOSAIC VEGETATION IN SOUTHWESTERN IDAHO

Dana L. Yensen and Graham W. Smith

ABSTRACT: We described and mapped two desert shrub communities, a big sagebrush (Artemisia tridentata Nutt.)-winterfat (Ceratoides lanata [Pursh] J. T. Howell) mosaic and a big sagebrush-Nuttall saltbush (Atriplex falcata [Jones] Standl.) mosaic. The mean age of the winterfat population was 72 years; the mean age of the Nuttall saltbush population was 24 years. Recruiting of both winterfat and Nuttall saltbush has declined in recent years. Winterfat alternes are long-established. The presence of Nuttall saltbush may be disturbance-related.

INTRODUCTION

Two adjacent mosaic communities were investigated in the northwestern portion of the Birds of Prey Study Area in Ada County, southwestern Idaho. One mosaic was composed of alternes dominated by big sagebrush (Artemisia tridentata Nutt.) and winterfat (Ceratoides lanata [Pursh] J. T. Howell). The other was composed of alternes of big sagebrush and Nuttall saltbush (Atriplex falcata [Jones] Standl.). These mosaic communities were broadly ecotonal between big sagebrush communities to the north and salt-desert shrub communities to the south. The study area lies on the southwestern portion of the Snake River Plain, a basalt plateau. The topography is rolling. Soils supporting the mosaic communities are deep silt loams and fine sandy loams (USDA Soil Conservation Service and others 1980). Annual precipitation, most of which falls in winter and spring, averages 10 in (25.4 cm). Summers are hot and dry and winters are mild. Cattle and sheep graze the area in spring and fall (USDI, Bureau of Land Management 1979).

Two photographs taken of part of the big sagebrush-winterfat mosaic around 1900-10,[1] show that this mosaic existed at the turn of the century. Beginning in the 1870's, the area suffered many decades of grazing abuse, and rapid reduction in the acreage occupied by winterfat occurred. Though there were many historic references to the presence of winterfat, we could find none to Nuttall saltbush (Yensen 1980). The lack of early references to Nuttall saltbush could be explained in two ways. The plant is neither as conspicuous nor as easily identified as winterfat, especially when dormant. Early observers may have included it in descriptions of shadscale (Atriplex confertifolia [Torr. & Frem.] Wats.) or other Atriplex vegetation. Alternatively, Nuttall saltbush may not have then been abundant enough to warrant notice.

Heavy grazing may favor Atriplex species at the expense of winterfat (Holmgren and Hutchings 1972). Also, we observed small areas (usually less than 1 acre [0.405 ha]) where Nuttall saltbush has replaced winterfat near stock watering tanks and sheep bedding camps. Both historic records and these observations suggest that while winterfat was a long-established component of the mosaic, Nuttall saltbush could be adventive.

METHODS

In 1979, stands of the mosaic communities were delineated and mapped on USGS 7.5-minute topographic maps, using color aerial photographs. All boundaries were ground-checked. Only stands 40 acres (16.2 ha) or larger were mapped. Twenty-two stands of big sagebrush-winterfat mosaic (25,823 acres [10,450.42 ha]) and ten stands of big sagebrush-Nuttall saltbush mosaic (7,062 acres [2,857.95 ha]) were identified. The vegetation in each stand was sampled in 1979 using the canopy coverage technique of Daubenmire (1959). Canopy coverage of all species was estimated from forty 10.8-ft^2 (1-m^2) plots at 34-ft (10-m) intervals along a 1,312-ft (400-m) transect in each stand. Fifteen circular shrub density plots were sampled along each canopy transect in the manner of Asherin (1973). Each shrub density plot was 1/300 acre (0.0014 ha). The number of shrubs in the plots and the average height were recorded for each species.

In the fall of 1981, much of the area occupied by big sagebrush-Nuttall saltbush mosaic burned, leaving only a few small remnant stands no larger than a few dozen acres.[2]

In 1983, two sampling sites were located where ecotones between alternes of winterfat and Nuttall saltbush were present. Two transect sets were established 196.85 ft (60 m) apart at each sampling site. Each of the transect sets consisted of nine parallel sampling lines, each

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[1]Bowen, C. F. Photos #25 and #26, Sinker Butte on the Snake River Plateau, 8 miles E. of Murphy, 30° E. Available from the U.S. Geological Survey Photographic Library, Denver, Colo.

[2]USDI, Bureau of Land Management, Boise, ID. District unpublished fire records; 1981.

60 ft (15.24 m) long and 131.23 ft (40 m) apart (fig. 1). The center line of the nine, called line 0, was arbitrarily placed in the visual center of the ecotone, along its length. Lines in each transect set were numbered from line 0 into each alterne: lines 1W, 2W, 3W, and 4W were placed 131.23 ft (40 m), 262.47 ft (80 m), 393.70 ft (120 m), and 524.93 ft (160 m), respectively, into the winterfat alterne. Lines 1N, 2N, 3N, and 4N were placed 131.23 ft (40 m), 262.47 ft (80 m), 393.70 ft (120 m), and 524.93 ft (160 m), respectively, into the Nuttall saltbush alterne. Lines 3 and 4 were located well within "pure" assemblages of each respective shrub.

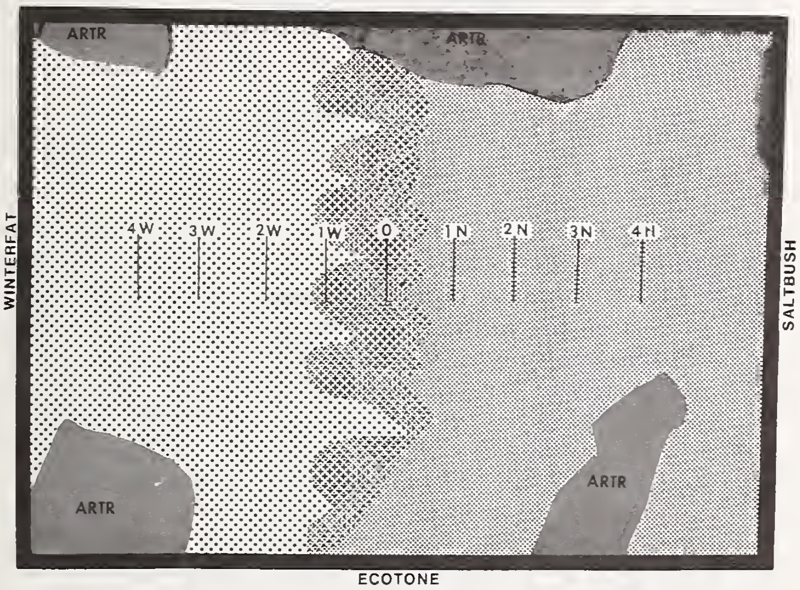

Figure 1.--Schematic diagram of the nine sampling lines of a transect set. Lines are 60 ft (15.24 m) long and 131.23 ft (40 m) apart. Dark areas are big sagebrush alternes.

On each sampling line, the total number of line hits of living and dead individuals was recorded for both species. We searched for seedlings on all sampling lines. At 2-ft (60.96-cm) intervals on each sampling line, the winterfat or saltbush individual nearest that point was removed for aging by vascular ring count (30 plants per line). A total of 1,183 shrubs were ring-counted, 484 winterfat and 619 Nuttall saltbush.

Since woody chenopods do not form vascular rings in the same manner as do most other woody dicots (Stebbins 1972) and, rarely, may produce more than one vascular ring per year (Stewart and others 1940), ages determined by counting vascular rings in winterfat and Nuttall saltbush may not be as accurate as ages assigned by vascular ring-count to species such as big sagebrush.

Also, since these chenopods have very complacent rings, their ages cannot be determined by correlation with nearby sensitive-ring species like big sagebrush (Davis and others 1972). However, several workers have found aging chenopods by vascular ring count to be a reliable and useful technique (Stewart 1935; Stewart and others 1940; Strickler 1956). Because both winterfat and Nuttall saltbush are chenopods, the technique is likely to be comparative. In our results, age in years represents the highest continuous count of vascular rings per shrub.

RESULTS

Canopy coverage of all major species revealed great similarities in the structure and composition of the two communities (tables 1 and 2). Average densities and heights of big sagebrush were also similar in both mosaics.

Table 1.--Composition of big sagebrush-winterfat community.

Species	Percent canopy coverage	Percent frequency	Density (no. per acre)	Height (inches)
Artemisia spinescens	.6	27	141.80	5.31
Artemisia tridentata	7.2	100	1,537.27	20.12
Atriplex confertifolia	.1	9		
Grayia spinosa	1.0	36	113.64	20.20
Ceratoides lanata	10.8	100	8,419.71	6.61
Bromus tectorum	5.4	55		
Festuca octoflora	1.6	59		
Poa secunda	5.1	95		
Sitanion hystrix	1.3	77		
Salsola iberica	trace	5		
Sisymbrium altissimum	trace	5		
Descurainia spp.	.9	55		
other forbs	2.1	82		

Table 2.--Composition of big sagebrush-Nuttall saltbush community.

Species	Percent canopy coverage	Percent frequency	Density (no. per acre)	Height (inches)
Artemisia spinescens	.2	10	139.98	11.42
Artemisia tridentata	8.9	100	1,587.94	20.71
Atriplex falcata	3.7	100	3,231.89	4.72
Grayia spinosa	.6	30		20.08
Bromus tectorum	6.5	50		
Vulpia octoflora	.9	50		
Poa secunda	5.3	80		
Sitanion hystrix	1.0	70		
Descurainia spp.	.7	50		
other forbs	2.1	60		

Dead plants of winterfat were uncommon on all sampling lines. Dead saltbush plants on the saltbush sampling lines were more numerous as the distance from the ecotone increased (fig. 2). Fewer individuals of winterfat and Nuttall saltbush were found on 0 (ecotone) and 1W lines than on any other sampling lines. No seedlings of either species were encountered. No fire-charred living or dead shrubs were found.

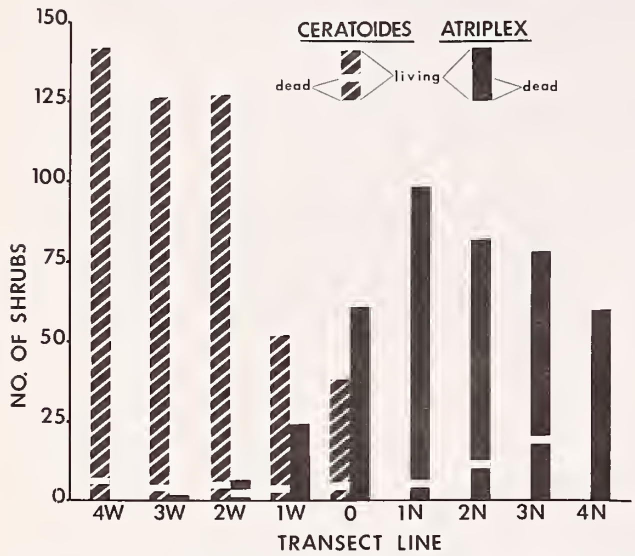

Figure 2.--Frequency (line hits) of living and dead winterfat and Nuttall saltbush on sampling lines (60 ft [15.24 m] long, 131.23 ft [40 m] apart), across ecotones between alternes of each.

The youngest winterfat individual was 22 years old, and the oldest 136 years. The mean age of winterfat was 72 years (fig. 3). Most winterfat were older than the ages we recorded; only 7 of 484 winterfat we aged had intact cores. The youngest Nuttall saltbush was 3 years old, and the oldest 61 years. The mean age of Nuttall saltbush was 24 years (fig. 4).

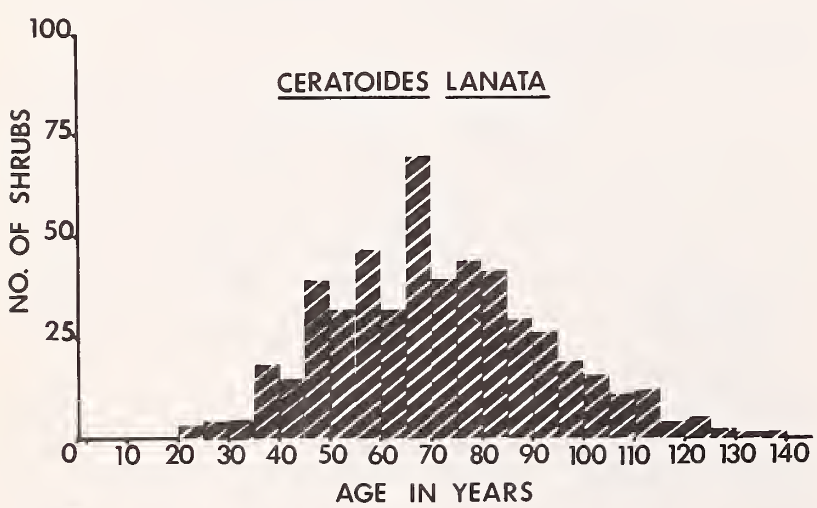

Figure 3.--Age distribution of winterfat population in the sampling area.

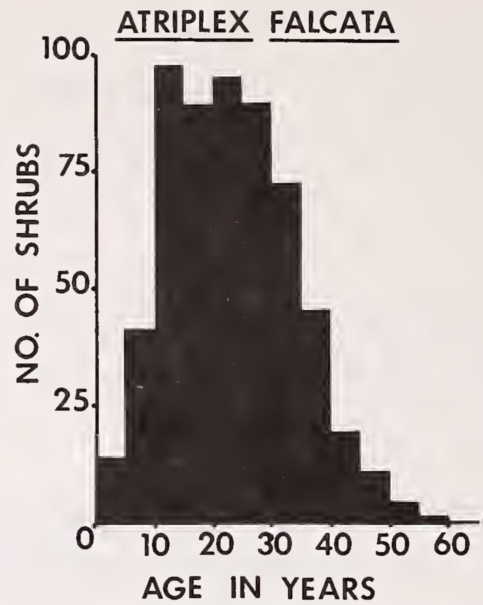

Figure 4.--Age distribution of Nuttall saltbush population in the sampling area.

Ages of plants on each sampling line were compared using one-way ANOVA (Nie and others 1975) with a priori contrasts using the t statistic. Mean ages of winterfat were not significantly different between sampling lines except between lines 2W and 4W ($p<0.01$); age of winterfat on ecotonal lines (0) was significantly different from the age of winterfat on each of the other lines (table 3).

Table 3.--Comparisons among mean ages of winterfat (W sampling lines) and Nuttall saltbush (N sampling lines) in the ecotone (0) and at increasing distances from it (a priori t contrasts). (See fig. 1 for sampling line scheme).

		1W	2W	3W	4W	0 W	0 N	1N	2N	3N	4N
	1W	--									
	2W	ns	--								
	3W	ns	ns	--							
	4W	ns	.01	ns	--						
0	W	.05	.001	.05	ns	--					
0	N	.001	.001	.001	.001	.001	--				
	1N	.001	.001	.001	.001	.001	.001	--			
	2N	.001	.001	.001	.001	.001	.001	ns	--		
	3N	.001	.001	.001	.001	.001	.05	ns	.01	--	
	4N	.001	.001	.001	.001	.001	.001	ns	ns	ns	--

Winterfat plants scattered through the saltbush alternes were so rare that none were recorded on any of the sampling lines. However, saltbush was present in small amounts in the winterfat alternes (fig. 2).

DISCUSSION

If either winterfat or Nuttall saltbush were invading the adjacent alterne of the other species, we would expect the invading species to be younger closer to and within the ecotone. The mean age of a non-invading shrub species would be similar within the ecotone and at all distances from it. For an invading species, one would expect fewer dead plants and more seedlings closer to the ecotone, while for a non-invading species one might expect more dead plants and fewer seedlings closer to the ecotone.

Winterfat has long occupied the winterfat alternes, since each winterfat sampling line (and all 0 lines) had winterfat plants over 100 years old. Nuttall saltbush is obviously shorter-lived than winterfat (figs. 3 and 4). The lower mean age of saltbush on the ecotone lines may indicate that saltbush is expanding into the winterfat alternes. Although mean winterfat ages were lower on ecotone lines than elsewhere, this is the result of no winterfat in the 104 to 136-year range in the ecotone. In fact, winterfat on the ecotone lines had the highest minimum age recorded on any group of sampling lines (34 years), indicating that this species is less reproductively successful in the ecotone.

Dead winterfat were uncommon on all sampling lines. As we would expect for an invading species, no dead saltbush were recorded on lines 0 or on lines 1W, and dead saltbush in the saltbush alternes were more frequent at increasing distances from the ecotone (fig. 2). Total numbers of dead saltbush were much higher than total numbers of dead winterfat. This can be attributed to the shorter life span of saltbush, with the shorter "turnover time" generating more dead plants (Bamberg and others 1980). It is also possible that there are many dead saltbush because this species is subject to periodic insect attacks, which can result in high mortality.[3] The low numbers of both winterfat and Nuttall saltbush on lines 0 and 1W may indicate competition between the species where both are present in numbers.

One result of our investigation was the discovery of diminished levels of recruiting of both species in recent years, especially winterfat. Recruiting of Nuttall saltbush has fallen off only during the past decade. However, the winterfat population has recruited virtually no new individuals in 20 years. We found more winterfat older than 100 years than winterfat younger than 30 years.

Strickler (1956) called a Nevada winterfat population "overmature." Plants 2 to 6 years old made up 15 percent of the population; 70 percent of the plants were from 35 to 65 years old.

[3] Lee Sharp, personal communication; 1983.

Stewart (1935) found a Utah winterfat population in which 7 percent of the plants sampled had ring counts of 21 or fewer. He stated that this population was in danger of extinction in one or two plant generations. Norton (1978) studied a Utah winterfat community in which just over half of the plants were what he called "old"--40 years old or older. In comparison, the winterfat age profile in our sampling area is heavily skewed toward very old plants.

Stewart, Cottam, and Hutchings (1940) studied the vegetation of three adjacent Utah valleys and aged the winterfat populations in each by vascular ring count (fig. 5). Snake Valley they described as lightly grazed, and grazed only in winter. Pine Valley was characterized as heavily grazed during the previous 20 years and moderately grazed before that time. Wah Wah Valley had been heavily grazed from the time of white settlement until the time of their study. All populations contained individuals less than 10 years old. Snake Valley, with the lowest level of grazing use, showed a winterfat age profile more skewed toward younger plants, although very old plants were also present. The age profile of the winterfat in Wah Wah Valley was the most similar to the age profile of winterfat in our sampling area. Both populations, having a long early history of abusive grazing, contained few young individuals and many very old plants.

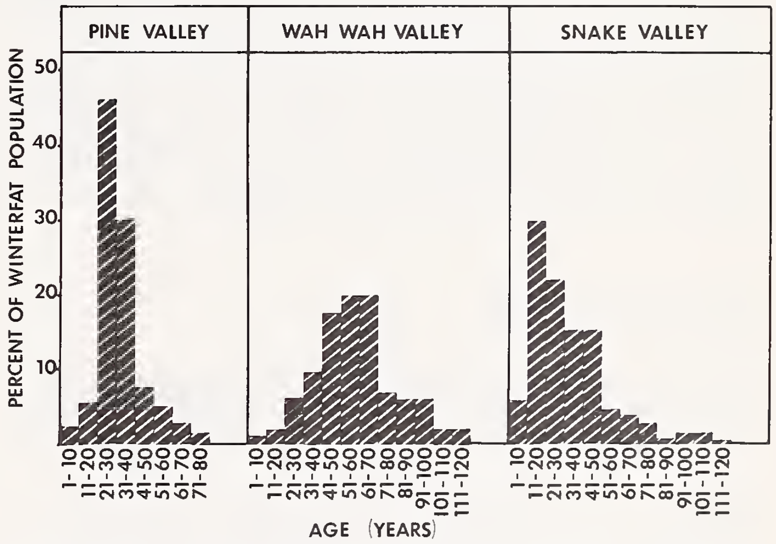

Figure 5.--Age distribution of winterfat populations in Pine, Wah Wah, and Snake Valleys, Utah. After Stewart, Cottam, and Hutchings (1940).

What changes in the study area have occurred during the past three decades which may have affected winterfat recruiting? The annual precipitation in the area has not been unusually low, high, or odd-timed (USDI, BLM 1979). Winterfat, in fact, may be favored over Atriplex during times of prolonged drought (Holmgren and Hutchings 1972). The 14-year drought which ended in 1934 (Pechanec and others 1937) did not curtail recruiting of winterfat in the sampling area, as the age profile of the population indicates.

Recruiting for both species, however, is probably rather sporadic in this variable climate. A good year for seedling production occurs perhaps only once or twice a decade.[4] A recent (1955 to present) development[5] which may have had an effect is the placement of stock watering tanks in the Birds of Prey Study Area. This has allowed higher levels of grazing at dry times of the year (late spring and fall). Timing of grazing may be as important to winterfat as grazing intensity (Holmgren and Hutchings 1972).

It is not known whether Nuttall saltbush dominated some mosaic alternes in the Birds of Prey Study Area during presettlement times. Nuttall saltbush alternes may have been present then, but were unrecorded. Possibly, however, Nuttall saltbush replaced winterfat in a portion of the big sagebrush-winterfat mosaic quite rapidly many decades ago when winterfat was injured by abusive grazing. Nuttall saltbush may have always been present in the winterfat alternes in low numbers. That Nuttall saltbush was a part of winterfat communities is supported by the fact that we found saltbush individuals scattered throughout winterfat alternes, and that these saltbush (on winterfat sampling lines 1W, 2W, and 3W) included plants older than the mean ages of saltbush in the saltbush alternes.

Further study of these mosaic communities would be rewarding. Comparisons of soil carbon isotope ratios in alternes of each species, such as those done in Utah by Dzurek (1980) (in a winterfat-shadscale ecotone) might be very useful in understanding the stability and tracing the vegetation history of these alternes. Lack of recruiting by both species, especially winterfat, should be of special concern to users and managers of the area.

PUBLICATIONS CITED

Asherin, D. A. Big game winter range inventory. Job Completion Rep. W-154-R-1, Study I. Boise, ID: Idaho Fish and Game Dept.; 1973. 29 p.

Bamberg, S. A.; Wallace, A.; Romeny, E. M.; Hunter, R. E. Further attributes of perennial vegetation in the Rock Valley area of the northern Mojave Desert. Great Basin Nat. Mem. 4: 39-41; 1980.

Daubenmire, R. A canopy-coverage method of vegetational analysis. Northwest Sci. 33: 43-64; 1959.

Davis, J. B.; Tueller, P. T.; Bruner, A. D. Estimating forage production from shrub ring widths in Hot Creek Valley, Nevada. J. Range Manage. 25: 398-402; 1972.

[4]USDI Bureau of Land Management. Boise, Idaho, District unpublished grazing records; 1935-79.

[5] Lee Sharp, personal communication; 1983.

Dzurek, R. S. Carbon isotope ratios of soil organic matter and their use in assessing community composition changes in Curlew Valley, Utah. Logan, UT: Utah State University; 1980. 59 p. Thesis.

Holmgren, R. C; Hutchings, S. S. Salt desert shrub response to grazing use. In: McKell, C. M.; Blaisdell, J. P.; Goodin, S. R. eds. Wildland shrubs--their biology and utilization. 1971 July; Utah State University, Logan, UT. Gen. Tech. Rep. INT-1. Ogden, UT: U.S. Deptartment of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1972: 153-165.

Nie, N. H.; Hull, C. H.; Jenkins, J. G.; Steinbrenner, K.; Bent, D. H. Statistical package for the social sciences. 2nd ed. New York: McGraw-Hill; 1975. 675 p.

Norton, B. E. The impact of sheep grazing on long-term successional trends in salt desert shrub vegetation of southwestern Utah. In: Hyder, D. N., ed. Proceedings of the first international rangeland congress; 1978 August 14-18; Denver, CO. Denver, CO: Society for Range Management; 1978: 610-613.

Pechanec, J. F.; Pickford, G. D.; Stewart, G. Effects of the 1934 drought on native vegetation of the upper Snake River Plains, Idaho. Ecology 18: 490-505; 1937.

Stebbins, G. L. Evolution and diversity of arid-land shrubs. In: McKell, C. M.; Blaisdell, J. P.; Goodin, S. R., eds. Wildland shrubs--their biology and utilization; 1971 July; Utah State University, Logan, UT. Gen. Tech. Rep. INT-1. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1972: 111-120.

Stewart, G. Plant cover and forage conditions on spring-fall and winter ranges, largely on public domain lands in the Intermountain region. Utah Juniper. 6: 9-13; 1935.

Stewart, G.; Cottam, W. P.; Hutchings, S. S. Influence of unrestricted grazing on northern salt desert plant associations in western Utah. An intensive study of range deterioration. J. Agric. Res. 60: 289-316; 1940.

Strickler, G. S. S. Factors affecting the growth of the sage (Eurotia lanata [Pursh] Moq.). Reno, NV: University of Nevada; 1956. 125 p. Thesis.

U.S. Department of Agriculture, Soil Conservation Service; U.S. Department of the Interior, Bureau of Land Management; University of Idaho, College of Agriculture; Idaho Agricultural Experiment Station; Idaho Soil Conservation Commission. Soil survey of Ada County area, Idaho; 1980. 327 p. Maps.

U.S. Department of the Interior, Bureau of Land Management. Snake River birds of prey special research report to the Secretary of the Interior. Boise, ID: 1979. 142 p.

Yensen, D. A grazing history of southwestern Idaho with emphasis on the Birds of Prey Study Area. Prog. Rep. Contract 52500-CT5-1002. Boise, ID: U.S. Department of the Interior, Bureau of Land Management; 1980. 82 p.

In: Tiedemann, Arthur R.; McArthur, E. Durant; Stutz, Howard C.; Stevens, Richard; Johnson, Kendall L., compilers. Proceedings--symposium on the biology of Atriplex and related chenopods; 1983 May 2-6; Provo, UT. General Technical Report INT-172. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 309 p.

FLAVONOID AGLYCONES OF DIPLOID AND POLYPLOID *ATRIPLEX CONFERTIFOLIA*

Stewart C. Sanderson and Howard C. Stutz

ABSTRACT: Although diploids and polyploids (4*n*, 6*n*, 8*n*, 10*n*) of *Atriplex confertifolia* (Torr. & Frem.) S. Wats. are morphologically quite similar, they differ in some of their flavonoid constituents. All have the 6-H flavonols isorhamnetin and quercetin but only polyploids contain the 6-methoxy flavonols spinacetin and patuletin. Consequently flavonoid content is useful in distinguishing diploids from polyploids. Because of the morphological resemblance between ploidy levels and because of a lack of suitable alternative parents it is believed that the polyploid races of *A. confertifolia* are autoploids. The presence of unique flavonols in polyploids is therefore probably caused by a change in genetic regulation incident to polyploidy, and may be the result of heightened production of compounds which in diploids are intermittently produced or are present only in small amounts. Because of the genetic redundancy of polyploids and consequent reduced effectiveness of natural selection, introgression of the genetic basis for this chemical difference from other species seems unlikely.

INTRODUCTION

Atriplex confertifolia (Torr. & Frem.) S. Wats. (shadscale), a spiny shrub species dominant over many areas of the western United States, consists of a series of chromosome races (2*n*, 4*n*, 6*n*, 8*n*, and 10*n*) (Stutz and Sanderson 1983). Only two populations of hexaploids and one population of decaploids have been found, but diploids, tetraploids, and octaploids are widespread. Diploids are restricted to more central and northern parts of the range and are usually in less xeric sites than those occupied by polyploids. Some of the existing variation in stature and other characteristics between different populations within a chromosome race may be due to plastic response to differences in moisture or other environmental factors but much of it appears to be genetic. The diploids and decaploids are generally larger than the tetraploids, hexaploids, and octoploids, but otherwise all of the chromosomal races are so similar that it seems unlikely that whole genomes of any other species are involved in their origin. *A. confertifolia* races are therefore likely autoploid rather than alloploid.

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METHODS

Flavonoids were isolated by column chromatography and identified using ultraviolet shift spectroscopy (Markham and Mabry 1975). Where helpful, comparison was made with standard compounds isolated from appropriate sources (spinacetin from spinach and 8-methoxylated and 6, 8-dimethoxylated compounds from lemon peel). Demethylation of these compounds was carried out by heating with pyridinium hydrobromide and a trace of water; the more labile compounds were demethylated under nitrogen.

Leaf samples of about 1/5 oz. from individual plants or from populations (leaves from five or more plants mixed together) were air dried and hydrolyzed with 1N HCl for 1 hour in a boiling water bath. Leaves were then drained, ground in a mortar, and the resulting slurry stirred with portions of diethyl ether. The ether was then decanted and the residue after evaporation was washed with a small amount of methanol. Maximal amounts of the resulting solution were spotted on half-sheets (28.5 x 46 cm) of Whatman 3mm chromatography paper; the amount spotted was adjusted to afford the best detectability of faint compounds while avoiding overloading.

Chromatograms were run the short direction in 15 percent acetic acid, overrun to about 2 times normal running time. Four sheets at a time were run the second (long) direction in acetic acid-water-benzene (96:4:100 v/v/v), in a (18 x 25 x 56 cm) non-preequilibrated chamber. To aid visualization and to retard decomposition of air-labile compounds, chromatograms were sprayed with 2 percent methanolic aluminum chloride. They were examined in long-wave ultraviolet light.

RESULTS

The 6-methoxy flavonols, spinacetin and patuletin, plus isorhamnetin and quercetin were found in leaves of the polyploid races of *A. confertifolia* (except 4*n* *A. confertifolia*

from Barstow). Only isorhamnetin and quercetin, plus traces of kaempferol, were detected in diploids (figs. 1, 2 and table 1). Certain of the additional Atriplex species which were examined had the same diploid-polyploid flavonoid distribution as A. confertiflora, but A. corrugata had a constant pattern regardless of ploidy.

DISCUSSION

Because secondary products such as polyphenols are typically produced only at certain times or in certain plant parts such as leaves, leaf glands, or stems, their synthesis may often be altered by mechanisms of internal genetic control. Expression of flavonoids has been found to be limited in tissue culture, possibly because under these conditions certain cell organelles or plant parts, and consequently certain chemical products, are not formed (Forrest 1969; Thorpe and others 1971). Polyploidy apparently may be sufficient to similarly upset such control mechanisms (Haskell 1968; Levy 1976; Murray and Williams 1976; Mears 1980; and Levin 1983). However, normally, chemical markers are identical in diploids and autotetraploids derived from them (Soltis and others 1983).

Since Atriplex confertifolia is known to hybridize freely with several other Atriplex species (Stutz, this volume), an alternative explanation for the chemical differences between diploid and polyploid races in the species might be that the capacity for unique flavonoid synthesis in the polyploids was introduced by hybridization. Diploids could have escaped receiving any 6-methoxylation genes because of a reduced tendency to hybridize, as compared to polyploids, and also because of a tendency for plants of a given ploidy level to exchange genes only with others of the same level. The closest relatives of A. confertifolia according to Hall and Clements (1923) are A. parryi S. Wats. and A. spinifera Macbr. But while hybridization of A. confertifolia with these two species may exist,

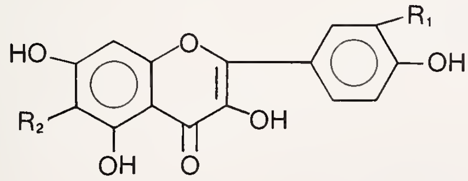

Figure 1.-- Flavonols of Atriplex confertifolia
spinacetin $R_1 = OCH_3$, $R_2 = OCH_3$,
patuletin $R_1 = OH$, $R_2 = OCH_3$
isorhamnetin $R_1 = OCH_3$, $R_2 = H$;
quercetin $R_1 = OH$, $R_2 = H$
kaempferol $R_1 = R_2 = H$

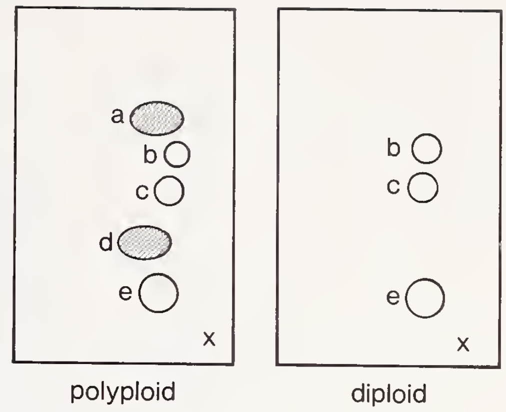

Figure 2.-- Paper chromatography of flavonoid aglycones of Atriplex confertifolia. Compounds shown are a. spinacetin, b. isorhamnetin, c. kaempferol, d. patuletin, and e. quercetin.

it has not yet been reported, although populations of A. confertifolia within the region of sympatry with A. parryi appear to carry a hint of past hybridization with that species. However since none of the samples of A. spinifera which we have examined have shown any evidence of spinacetin nor patuletin, they do not appear to be likely candidates for the source of these compounds. A. corrugata S. Wats. and A. parryi do have the required compounds on the diploid level, and so perhaps they could have served as a source. However, extensive interspecific and interploid gene flow would have been required to achieve the apparent universal presence of chemical markers throughout both the numerous polyploid populations of A. confertifolia and also of other species with the same type of diploid-polyploid flavonoid distribution. Considering the genetic redundancy of polyploids, gene flow of that magnitude would have required a strong selective advantage, to say the least, but no advantage at all has yet become apparent.

It seems likely therefore, that the flavonol 6-methoxylating ability of polyploids is best explained on the basis of modified regulation of genes which, although in fact present in diploids, are not prominently expressed. The activity of such genes might be restricted to particular organs in diploids, or might be expressed only in unusual circumstances. Because "constant" selection over time would be required to preserve the functional integrity of the relevant genes from loss through mutation, it must be supposed that, when present, the 6-methoxylating ability does serve some useful purpose. Reported functions of flavonoids include formation of sunscreens, enzyme cofactors, enzyme inhibitors, precursors of toxic substance, contributors to pigmentation, and defense agents (McClure 1975). Perhaps increased information regarding function, as suggested by Zucker (1983) will make the present case more understandable.

Table 1.-- Populations of Atriplex confertifolia examined by flavonoid chromatography.

Species	Ploidy	Location	Flavonoids 6-OMe	6-H
A. confertifolia	2N	Pocatello, Bannock Co., Idaho	0	+
(Torr. & Frem.)	2N	Hardin, Big Horn Co., Montana	0	+
S. Wats.	2N	S end of Snake Range, White Pine Co., Nevada	0	+
	2N	Painted Hills, Wheeler Co., Oregon	0	+
	2N	Antelope Island, Davis Co., Utah	0	+
	2N	5 mi W of Fairfield, Utah Co., Utah	0	+
	2N	10 mi E of Fry Canyon, San Juan Co., Utah	0	+
	2N	Harley Dome, Grand Co., Utah	0	+
	2N	Horse Canyon turnoff, hwy US 6/50, Emery Co., Utah	0	+
	2N	Moore rd exit, hwy I-80, Emery Co., Utah	0	+
	2N	Alcova, Natrona Co., Wyoming	0	+
	2N	2 mi E. of Worland, Washakie Co., Wyoming	0	+
	4N	25 mi W of Barstow, San Bernadino Co., California	0	+
	4N	N end of Spring Valley, White Pine Co., Nevada	+	+
	4N	15 mi S of Wendover, Elko Co., Nevada	+	+
	4N	Cottonwood Creek, Kane Co., Utah	+	+
	4N	3 mi E of Faust, Tooele Co., Utah	+	+
	4N	3 mi E of Fry Canyon, San Juan Co., Utah	+	+
	4N	1 mi W of Horse Canyon turnoff, hwy US 6/50, Emery Co., Utah	+	+
	4N	5 mi N of Montezuma Creek, San Juan Co., Utah	+	+
	4N	Wellington, Carbon Co., Utah	+	+
	4N	Westwater Creek, Grand Co., Utah	+	+
	4N	2 mi N of Alcova, Natrona Co., Wyoming	+	+
	6N	16 mi E of Four Corners, Montezuma Co., Colorado	+	+
	6N	10 mi S of Cortez, Montezuma Co., Colorado	+	+
	6N	5 mi N of Green River in Grand Co., Utah	+	+
	8N	Barstow, San Bernardino Co., California	+	+
	8N	Boron, Kern Co., California	+	+
	8N	Newberry Springs, San Bernardino Co., California	+	+
	8N	Glendale, Clark Co., Nevada	+	+
	8N	20 mi S of Deseret, Millard Co., Utah	+	+
	8N	½ mi E of Faust, Tooele Co., Utah	+	+
	8N	10 mi S of Rowley, Tooele Co., Utah	+	+
	10N	1 mi S of Eskdale, Millard Co., Utah	+	+
	10N	15 mi E of Garrison, Millard Co., Utah	+	+
A. canescens[1]	2N	Las Cruces, Dona Ana Co., New Mexico	0	+
(Pursh) Nutt.	2N	Zia Pueblo turnoff, hwy NM 44, Sandoval Co., New Mexico	0	+
	2N	Little Sahara Dunes, Juab Co., Utah	0	+
	4N	Page, Coconino Co., Arizona	+	+
	4N	Carson City, Carson Co., Nevada	+	+
	4N	Montello, Elko Co., Nevada	+	+
	4N	Orem, Utah Co., Utah	+	+
A. corrugata	2N	5 mi E of Green River in Grand Co., Utah	+	+
S. Wats.	2N	15 mi N of Ouray, Uintah Co., Utah	+	+
	4N	Cainville, Wayne Co., Utah	+	+
	4N	Thompson, Grand Co., Utah	+	+
	4N	Wellington, Carbon Co., Utah	+	+

(con.)

Table 1.--(con.)

Species	Ploidy	Location	Flavonoids 6-OMe	6-H
A. cuneata A. Nels.	4N	Mack, Mesa Co., Colorado	+	+
	4N	Kirtland, San Juan Co., New Mexico	+	+
	4N	Cleveland, Emery Co., Utah	+	+
A. cuneata[2] ssp. introgressa C. Hanson	2N	15 mi NW of Maybell, Moffat Co., Colorado	0	+
	2N	Jensen, Uintah Co., Utah	0	+
	2N	5 mi N of Woodside, Emery Co., Utah	0	+
A. gardneri (Moq.) Dietr.	2N	4 mi E of Point of Rocks, Sweetwater Co., Wyoming	0	+
	2N	20 mi N of Rawlins, Carbon Co., Wyoming	0	+
	2N	Riner rd exit, hwy I-80. Sweetwater Co., Wyoming	0	+
	2N	8 mi N of Rocksprings, Sweetwater Co., Wyoming	0	+
	4N	Walden, Jackson Co., Colorado	+	+
	4N	Green River, Sweetwater Co., Wyoming	+	+
	4N	Rocksprings, Sweetwater Co., Wyoming	+	+
A. parryi[3] S. Wats.	2N	Newberry Springs, San Bernardino Co., California	tr	+
	2N	10 mi SW of Currant, Nye Co., Nevada	tr	+
	2N	2 mi S of Scotty's Junction, Nye Co., Nevada	tr	+
A. spinifera Macbr.	4N	Boron, Kern Co., California	0	+
	4N	Rosamond, Kern Co., California	0	+
	4N	Wasco, Kern Co., California	0	+

[1] A. canescens and allied species contain additional races at hexaploid and higher polyploid levels (in Mexico, the Mojave Desert and central Nevada) in addition to those races shown. Some of these resemble diploids in lacking 6-methoxyl flavonols, but differ from diploids in having an additional compound, the flavone tricin, whose distribution is under study.

[2] A. cuneata ssp. introgressa and A. gardneri produce, in addition to the compounds listed above, the 3-methyl ethers of isorhamnetin, quercetin and kaempferol, suggesting a phylogenetic relationship between these taxa.

[3] An additional 6-methoxylated compound is seen in small amounts in A. parryi and rarely on other species. It appears to be eupafolin (6-methoxy kaempferol).

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REFERENCES

Forrest, G. I. Studies on the polyphenol metabolism of tissue cultures derived from the tea plant (Camellia sinensis L.). Biochem. J. 113: 765-772; 1969.

Hall, H. M.; Clements, F.E. The phylogenetic method in taxonomy: the North American species of Artemisia, Chrysothamnus, and Atriplex. Carnegie Inst. Wash. publ. 326; 1923. 355 p.

Haskell, G. Biochemical differences between spontaneous and colchicine-induced autotetraploids. Heredity 23: 139-141; 1968.

Levin, D. A. Polyploidy and novelty in flowering plants. Am. Nat. 122: 1-25; 1983.

Levy, M. Altered glycoflavone expression in induced autotetraploids of Phlox drummondii. Biochem. Syst. Ecol. 4: 249-254; 1976.

Markham, K. R.; Mabry, T. J. Ultraviolet-visible and proton magnetic resonance spectroscopy of flavonoids. In: Harborne, J. B., Mabry, T. J.; Mabry, H. eds. The flavonoids. New York, NY: Academic Press; 1975: 45-77.

Mears, J. A. Chemistry of polyploids: a summary with comments on Parthenium (Asteraceae-Ambrosiinae). In: Lewis, W. H. ed. Polyploidy: its biological relevance. New York, NY: Plenum Press; 1980: 77-101.

McClure, J. W. Physiology and functions of flavonoids. In: Harborne, J. B.; Mabry, T. J.; Mabry, H. eds. The flavonoids. New York, NY: Academic Press; 1975:970-1055.

Murray, B. G.; Williams, C. A. Chromosome number and flavonoid synthesis in Briza L. (Gramineae). Biochem. Genet. 14: 897-904; 1976.

Soltis, D. E.; Bohm, B. A.; Nesom, G. L. Flavonoid chemistry of cytotypes in Galax (Diapensiaceae). Syst. Bot. 8: 15-23; 1983.

Stutz, H. C.; Pope, C. L.; Sanderson, S. C. Evolutionary studies of Atriplex: adaptive products from the natural hybrid 6N A. tridentata x 4N A. canescens. Amer. J. Bot. 66: 1181-1193; 1979.

Stutz, H. C; Sanderson, S. C. The role of polyploidy in the evolution of Atriplex canescens. In: Goodin, J. R. and D. K. Northington, eds., Arid land plant resources. Lubbock, Tx: Texas Tech Press, 1979: 615-621.

Stutz, H. C.; Sanderson, S. C. Evolutionary studies of Atriplex: chromosome races of A. confertifolia (shadscale). Am. J. Bot. 70: 1536-1547; 1983.

Thorpe, T. A., Maier, V. P.; Hasegawa, S. Phenylalanine ammonia-lyase activity in citrus fruit tissue culture in vitro. Phytochemistry. 10: 711-718; 1971.

Zucker, W. V. Tannins: does structure determine function: An ecological perspective. Am. Nat. 121: 335-336; 1983.

In: Tiedemann, Arthur R.; McArthur, E. Durant; Stutz, Howard C.; Stevens, Richard; Johnson, Kendall L., compilers. Proceedings--symposium on the biology of Atriplex and related chenopods; 1983 May 2-6; Provo, UT. General Technical Report INT-172. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 309 p.

Section 2. Ecological Relationships

AUTECOLOGICAL STUDIES WITH ATRIPLEX TRIANGULARIS WILLDENOW

Irwin A. Ungar

ABSTRACT: Investigations were conducted to determine the influence of biotic and abiotic factors on the seed ecology, growth, and distribution of Atriplex triangularis Willdenow. Both intraspecific and interspecific forms of competition reduce the growth of A. triangularis. Seed germination and growth are strongly inhibited by salinity concentrations above 2 percent NaCl. Seed production is reduced under conditions of biotic or abiotic stress, because the number of seeds produced by plants is directly related to plant size. Seed polymorphism provides for nondormant large seeds and the dormant small seeds which contribute to a permanent seed bank.

INTRODUCTION

Atriplex triangularis Willdenow (Chenopodiaceae) is an herbaceous annual halophyte which is commonly found in both inland and coastal salt marsh habitats (Osmond and others 1980). Although A. triangularis is capable of growing in highly saline environments, it also grows well under less saline conditions (McMahon and Ungar 1978; Riehl and Ungar 1983). Other species of Atriplex have been reported to have optimal growth under conditions of low salinity (Black 1956, 1960; Gale and Poljakoff-Mayber 1970). A. triangularis appears to be very plastic in its response to environmental conditions, varying from dwarfed unbranched organisms which produce few seeds in highly saline habitats to multibranched plants that produce large number of seeds in less saline environments. Binet (1967) has reported similar phenotypic plasticity in the French coastal species Atriplex babingtonii Woods and related it to differences in exposure to tidal action.

Recently there have been several excellent reviews of the literature by Osmond and others (1980), Kelley and others (1982), and Sharma (1982) concerning the ecology of species within the genus Atriplex. These reviews show that certain aspects of the autecology of these species have not been examined in great detail. Although the plant-soil relationships have been well documented for the salt desert shrubs Atriplex confertifolia (Torr. and Frem.) Wats., A. nuttallii Wats., and A. corrugata Wats. (Flowers 1934; Gates and others 1956; Branson and others 1967, 1970, 1976; Breckle 1976), less data are available concerning the salt tolerance of A. triangularis.

The limitation of A. triangularis to certain portions of the salinity gradient indicates that some biotic and/or abiotic factors are acting to control its distribution. Several authors suggest that high soil salinity would greatly repress the growth of halophytes and limit their distribution (Clarke and Hannon 1971; Waisel 1972; Mahall and Park 1976; Ungar and others 1979). Another possibility is that competition with more- and less-salt-tolerant species plays an important role in determining the growth rate and actual distribution of halophytes in a variety of habitats (Szwarcbaum and Waisel 1973; Zedler 1977; Barbour 1978). Because a combination of biotic and abiotic factors probably limits the distribution of halophytes, each system should be studied using the paradigm of Clarke and Hannon (1971) to determine the precise nature of the effect these various environmental factors have on growth and distribution of plants.

Species of Atriplex often are found in saline soils (Flowers 1934; Branson and others 1976; Breckle 1976; McMahon and Ungar 1978; Osmond and others 1980). In the inland salt pans of Ohio, Na^+ and Cl^- are the main components of saline soils (Riehl and Ungar 1983). These ions compose about 90 percent of the total dissolved solids in these soils. High Na^+ and Cl^- ion concentrations are characteristic of salt marsh soils in Kansas, Oklahoma, and Nebraska (Ungar 1974), and are, of course, characteristic of coastal marsh soil conditions (Chapman 1974). Salts in saline soils of the more northern and western portions of North America have higher proportions of sulfates and carbonates of magnesium and calcium than those of the coastal and southern prairie marshes (Ungar 1974; Breckle 1976). Seasonal changes in the salt content of inland saline soils of Ohio are characterized by lower spring and winter soil salinities and higher summer soil salinities, especially in the surface soils (McMahon and Ungar 1978; McGraw and Ungar 1981; Riehl and Ungar 1982, 1983). Higher soil salinities during the summer months are due mainly to two factors: drought periods, and high air temperatures accelerate evaporation which concentrates salts in the surface soils.

The salt marsh at Rittman, Ohio, in which most of these studies of A. triangularis have been completed, is located adjacent to a salt mining operation of the Morton Salt Company. The salt flat environment has five main vegetation zones. In order of occurrence along a gradient of decreasing soil salinity these include: Pan Salicornia, Salicornia, Atriplex, Hordeum, and Meadow. The Pan Salicornia zone is characterized by scattered individuals of S. europaea and the absence of other flowering plants. The highest soil salinities are found in this zone of the marsh, with electrical conductivities of the soil solution averaging 75 mmhos cm^{-1} through the growing season.

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The Salicornia zone is characterized by high density populations of S. europaea L., but it is occasionally associated with A. triangularis and Spergularia marina (L.) Griesb. in the less saline portions at the upper margin of this zone. Soil salinities in the Salicornia zone reach a maximum of 85.5 mmhos cm^{-1} electrical conductivity during midsummer (averaging 49 mmhos cm^{-1} through the growing season).

The Atriplex zone is dominated by A. triangularis, but Salicornia europaea, Spergularia marina and Hordeum jubatum L. are associated with it. Soil salinity levels average 33 mmhos cm^{-1} electrical conductivity, reaching as high as 85 mmhos cm^{-1} at the limits of A. triangularis distribution. In the high salt Atriplex area, A. triangularis is mixed with S. europaea. In the low salt area it is chiefly associated with Hordeum jubatum and Spergularia marina. Plants growing in the low salt area are larger and more branched than those in the high salt habitats. Figure 1 illustrates the small transition zone containing Atriplex which occurred at the edge of the Salicornia zone in 1981 and 1982. During earlier measurements on this 20-quadrat transect in 1975, A. triangularis was found growing in quadrats 6 through 15 (Ungar and others 1979), but increased soil salinity concentrations since 1978 have limited its distribution to quadrats 16 through 20 which were formerly dominated by Hordeum jubatum.

The Hordeum zone is dominated by H. jubatum. Associated with this species are scattered individuals of A. triangularis, Polygonum aviculare L., Agropyron repens (L.) Beauv., Convolvulus sepium L., and Poa compressa L. Soils in this area reach a maximum soil salinity level of 15 mmhos cm^{-1} and average 9 mmhos cm^{-1} during the growing season.

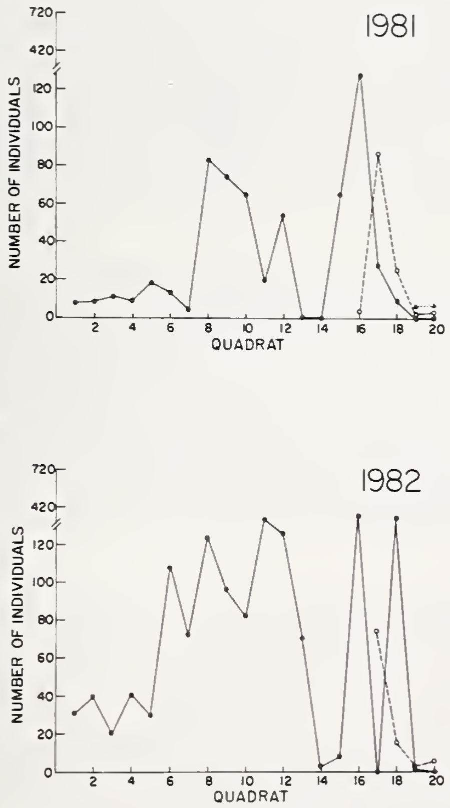


Figure 1.--Distribution of species in 1981 and 1982 along a salinity gradient at the Rittman, Ohio, salt marsh. Closed circles = Salicornia europaea. Open circles = Atriplex triangularis. Closed triangles = Hordeum jubatum.

The Meadow zone is composed of a mixture of old field species including Hordeum jubatum, Dipsacus sylvestris Huds., Juncus tenuis Willd., Juncus effusus L., Cyperus esculentus L., Typha angustifolia L., Phalaris arundinaceae L., Solidago spp., Daucus carota L., Rumex crispus L., Agropyron repens (L.) Beauv., Erigeron philadelphicus L., Panicum clandestinum L., and Chenopodium glaucum L. Soil salinity levels reach a maximum of 7 mmhos cm^{-1} electrical conductivity in this zone, averaging 3 mmhos cm^{-1}.

GROWTH-WATER POTENTIAL

Growth of Atriplex triangularis under field conditions is markedly affected by soil salinity conditions (table 1). Dry weight production under high salt conditions, averaging -3.0 MPa and ranging from -1.3 to -4.5 MPa, was only 3.5 percent of the production in low salt environments where the soil water potential averaged -0.9 MPa and ranged from -0.3 to -1.7 MPa through the growing season. A population of A. triangularis from one of the low salt habitats had high mortality, with few seed producing survivors, when it was inundated with highly saline water (-4.0 to -5.0 MPa) during September and October of the 1982 growing season. Black (1956), and Gale and others (1970) found a sharp reduction in dry weight production of other Atriplex species at salinity levels of -1.0 MPa and decreasing growth at more negative values.

Water status measurements of field plants, using a Wescor HR-33 dew point microvoltmeter equipped with a C-52 sample chamber, indicate that A. triangularis was capable of adjusting its water potential to that of the soil water potential. Data collected in 1979 show that in high salt environments (averaging -1.5 MPa) leaf osmotic potentials ranged from -2.4 to -4.7 MPa and leaf water potentials ranged from -1.7 to -4.1 MPa during the growing season when soil water potentials ranged from -0.7 to -2.9 MPa (table 2). Earlier investigations by Riehl and Ungar (1983) reported soil and plant water potentials more negative than -5.0 MPa in July, but in these locations A. triangularis plants did not survive to maturity. Water potential and osmotic potential measurements of Atriplex by Ungar (1977), Dejong (1979), and Richardson and McKell (1980) also showed that plants could adapt to media salinity levels. On a dry weight basis, approximately 15 percent of the shoot weight of plants growing in high salt environments and 5 percent of the shoot weight in low salt habitats can be attributed to inorganic ion accumulation. Other species of Atriplex have also been found to accumulate high concentrations of inorganic ions (Black 1960; Greenway and others 1966; Gale and others 1970; Sharma and others 1972; Breckle 1976; Storey and Wyn Jones 1979; Binet and Thammavong 1982).

Table 1.--Fresh weight and dry weight production of Atriplex triangularis plants growing in low salt and high salt environments.

	Low salt			High salt		
	Shoot	Root	Total	Shoot	Root	Total
Fresh weight (g)	12.280	0.297	12.577	0.700	0.014	0.714
± SD	3.612	0.125		0.273	0.004	
Dry weight (g)	2.435	0.112	2.547	0.084	0.005	0.089
± SD	0.605	0.045		0.032	0.002	
Shoot:root ratio (dry weight)		22:1			16:1	

Table 2.--Changes in soil water potential, and changes in osmotic potential (OP) and water potential (WP), of Atriplex triangularis leaves during the 1979 growing season. Data = MPa

	Soil		Leaf			
	Low salt	High salt	Low salt		High salt	
Date	WP	WP	WP	OP	WP	OP
31 March	0.6	0.7	[1]1.5	-	[1]1.7	-
30 April	1.1	1.6	1.6	1.9	3.3	3.6
26 May	0.4	0.7	1.1	1.5	2.0	2.4
27 June	1.9	2.9	3.3	3.6	3.3	4.0
30 August	0.9	1.3	2.4	2.7	2.9	3.5
27 September	0.5	1.6	2.2	2.4	4.1	4.7
28 October	1.1	1.6	2.0	2.9	3.0	3.6

[1]Cotyledon.

RESOURCE ALLOCATION

Harper (1977) reported that native annuals have reproductive efforts ranging from 15 to 30 percent of the total net resources allocated to plant organs, while in herbaceous perennial species reproductive effort accounts for 5 to 25 percent of the total. Few data are currently available regarding the allocation of resources to reproductive versus vegetative organs in the genus Atriplex (Osmond and others 1980; Kelley and others 1982; Sharma 1982). McMahon and Ungar (1978) reported that up to an average of 31 percent of the dry matter produced by field populations of A. triangularis was allocated to reproductive structures at the end of the growing season. There is an increase in relative allocation of dry matter to reproductive versus vegetative structures in these plants from July through September (table 3). Field data collected from saline environments in Ohio during 1980 and 1981 indicated values for reproductive effort of A. triangularis ranged from 25 to 37 percent of the total biomass production.[1] Plants in the high salt environments at the Rittman marsh in 1980 were dwarfed and they had fewer nodes than those plants growing in low salt habitats (table 4).

[1]Wertis and Ungar. Unpublished data, 1981.

Dry weight biomass data collected from plants of A. triangularis grown in the laboratory indicate that salinities up to 1 percent NaCl stimulated growth, while higher levels of salt stress were inhibitory (table 5). Resource allocation to vegetative structures remains fairly uniform at all salinities.

Seed production of plants from high salt environments was reduced to 33 percent of that in low salt habitats. Mean seed diameter and mean seed weight are lower in plants from less saline habitats. The small and large seeds collected from plants in the two zones did not have significantly different mean weights or mean diameters, but plants growing in low salt habitats were found to contain a greater proportion of small seeds.

The lowest resource allocation to seeds was in the 3.0 percent salinity treatment in which seeds only accounted for 7.8 percent of the total dry weight. At other salinity levels, seed weight accounted for from 11.0 to 12.3 percent of the total dry weight of plants (table 5). These results represent a fairly uniform resource allocation to vegetative and reproductive structures until salinity stress becomes limiting. At 3.0 percent NaCl the allocation to seeds is about 40 percent less than the optimal values and few viable seeds were produced. The number of seeds produced per plant varied with different levels of

Table 3,--Changes in resource allocation of Atriplex triangularis under field conditions during the growing season (from McMahon and Ungar 1978).

Month	Mean dry weight mg per $plant^{-1}$	Percentage of total		
		Root	Shoot	Reproductive
May	22.8	16.6	83.4	0.0
June	81.0	18.6	81.4	0.0
July	356.7	14.5	83.1	2.4
August	309.0	11.9	76.1	12.0
September	1071.8	11.5	57.5	31.0

Table 4.--Vegetative and reproductive characteristics of field populations of Atriplex triangularis growing in high salt and low salt environments.

Characteristic	High salt	Low salt
Plant height, cm $\pm$ SD	19.4 $\pm$ 2.5	33.9 $\pm$ 5.3
Nodes, No. $\pm$ SD	7.7 $\pm$ 1.4	15.4 $\pm$ 1.9
Seed number, $\pm$ SD	58.2 $\pm$ 15.7	185.0 $\pm$ 41.8
Seed diameter, mm $\pm$ SD	1.4 $\pm$ 0.05	1.2 $\pm$ 0.03
Seed weight, mg $\pm$ SD	1.0 $\pm$ 0.29	0.6 $\pm$ 0.15
Large seed	2.0 $\pm$ 0.04	2.0 $\pm$ 0.06
Small seed	0.5 $\pm$ 0.01	0.5 $\pm$ 0.01
Small:large seed ratio	6.1:1	63:1

Table 5.--Resource allocation of Atriplex triangularis plants grown under different salinity treatments.

NaCl %	Dry weight g. $plant^{-1}$	Percentage of total			
		Vegetative		Reproductive	
		Root	Shoot	Bract	Seed
0.0	1.78	29.8	51.7	6.2	12.3
0.5	2.45	25.3	53.1	10.6	11.0
1.0	2.05	24.4	52.2	12.2	11.2
2.0	1.22	20.5	51.6	15.6	12.3
3.0	0.51	27.5	52.9	11.8	7.8

salinity treatment (table 6). The largest number of seeds produced, a mean number of 541 seeds $plant^{-1}$, was observed in the 0.5 percent NaCl treated plants which also yielded the highest plant dry weight production.

A positive significant linear relationship exists between dry weight production and the number of seeds produced $plant^{-1}$, $Y = 24.52 + 224.52X$, $r^2 = 0.87$, $P<0.01$. Small plants produced fewer seeds than large plants and this relationship was most marked in the 3.0 percent NaCl treatment. The ratio of small to large seeds varied with salinity treatments, but remained fairly constant in salinity treatments ranging from 0.5 to 1.0 percent NaCl (table 6).

INTERSPECIFIC COMPETITION

Clarke and Hannon (1971), Szwarcbaum and Waisel (1973), Zedler (1977), and Ungar and others (1979) have indicated that interspecific competition was a significant factor affecting the distribution of halophytes. Competition studies indicated that some halophytes were better competitors in saline than freshwater conditions (Wilson 1967; Szwarcbaum and Waisel 1973; Gray and Scott 1977; Barbour 1978; Suehiro and Ogawa 1980). These data concerning the inability of halophytes to compete effectively with glycophytes explain why salt tolerant species such as Atriplex triangularis may not grow to maturity in low saline and non saline environments. Field investigations in

Table 6.--The effect of salinity on the number of seeds produced per Atriplex triangularis plant, and the ratio of small to large seeds.

NaCl %	Number of seeds per plant^{-1} Small	Large	Total	Ratio
0.0	361	87	448	4.4:1
0.5	366	175	541	2.1:1
1.0	311	152	462	2.0:1
2.0	235	162	397	1.5:1
3.0	71	2	73	35.5:1

native habitats are necessary to determine if species distributions are limited by salt stress or interspecific competition. Reciprocal transplants of species into different zones over an environmental gradient could provide additional evidence concerning the relative influence of biotic and abiotic factors on halophytic species distribution and growth (Clarke and Hannon 1971; Ungar and others 1979; Vince 1981).

Transplants of soil cores, averaging 2.5 in. (6 cm) in diameter and 4 in. (10 cm) in length, containing ten A. triangularis seedlings were made along two transects in May 1974. A total of five soil cores were transplanted into cleared and uncleared plots in each of the five vegetation zones. Survival was measured during July, August, and October 1974 (table 7). No A. triangularis plants survived in the pan zone containing scattered individuals of Salicornia europaea. This vegetation zone was subjected to the highest soil salinities, averaging greater than 40 mmhos cm^{-1} electrical conductivity throughout the growing season and reaching values as high as 145 mmhos cm^{-1} during the summer months. Transplants into the Salicornia zone also had low survival, averaging less than 5 percent in the four treatments, with no survivors in the cleared plots. High mortality could be attributed to the inability of A. triangularis to tolerate prolonged periods during the summer months with soil salinities averaging greater than 60 mmhos cm^{-1} electrical conductivity.

Survival in the other three zones ranged from 44 percent in the Atriplex zone to 61 percent in the Hordeum zone, with an intermediate value of 55 percent in the Meadow zone. Where plants survived in both cleared and uncleared plots, plants growing in the cleared plots had higher shoot and root dry weight production (fig. 2). Maximal biomass production for A. triangularis was obtained from cleared plots in the Meadow zone. A reduction in growth of A. triangularis plants in uncleared plots in the two less saline zones, Hordeum and Meadow, indicates that interspecific competition was important in determining both the level of plant production and the species distribution along this salinity gradient. Interspecific competion results in reduced growth and limits the root system of A. triangularis to the surface 2 inches (5 cm) of soil. This increases the chances of moisture stress injury in

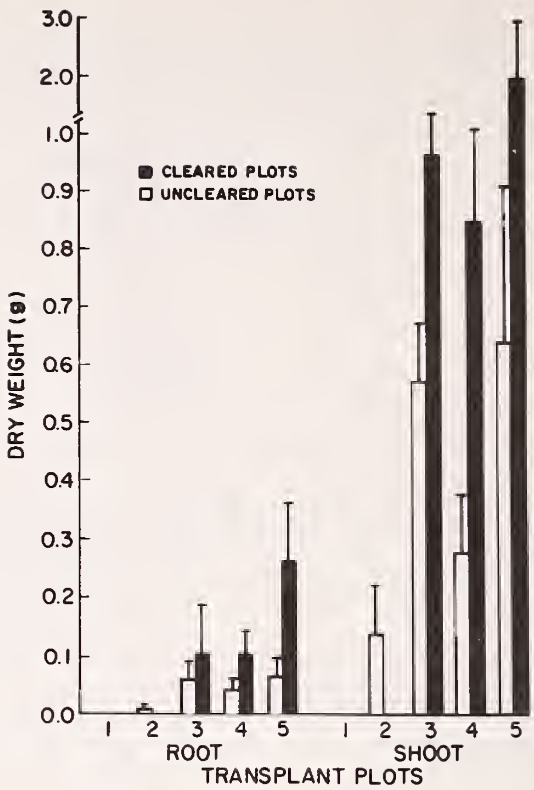


Figure 2.--Mean dry weight production of Atriplex triangularis plants transplanted into cleared and uncleared plots in five vegetation zones. 1. Pan Salicornia, 2. Salicornia, 3. Atriplex, 4. Hordeum, 5. Meadow.

the less saline zones and also increases salt stress injury in the highly saline zones.

INTRASPECIFIC COMPETITION VERSUS ABIOTIC STRESS

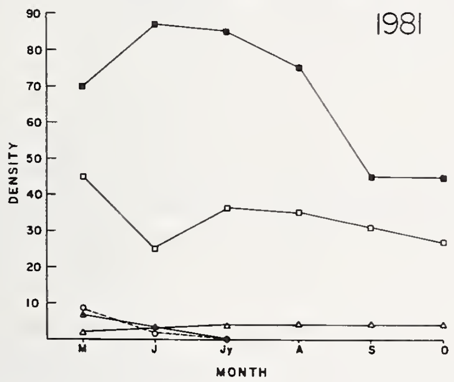
Both the size and survival of plants in many natural systems are considered to be controlled by density dependent factors (White and Harper 1970; Bazzaz and Harper 1976; Watkinson 1982). In studies with halophytes, Weaver (1918), Wendelberger (1950), Ungar and others (1979), and Jefferies and others (1981) concluded that mortality of plants is primarily due to abiotic factors. In their studies with Salicornia europaea populations in coastal and inland saline environments, Jefferies and others (1981), and Riehl and Ungar (1982) found that plant size and production were influenced by the initial densities of these populations. Further studies are needed to determine if there is a synergistic relationship between density dependent and density independent factors which affect growth and survival in saline environments.

Field transplant studies indicate that A. triangularis plants transferred back into the Atriplex zone had a 42 percent decrease in yield in uncleared plots compared to cleared plots (fig. 2). Data collected from thinning experiments in the field also indicate that biomass production is density dependent. Densities of 1, 10, 25, and 100 plants per 15.5 in.^{2} (100 cm^2) quadrat yielded dry weights of 188, 174, 93, and 60 mg plant^{-1} in each case respectively, indicating that high field densities can account for up to 70 percent reduction in yield of A. triangularis plants in pure stands.

Table 7.--Mean survival of 50 Atriplex triangularis plants in each zone on two transects along a salinity gradient. Ten plants were transplanted in each of five cores at each location in May. Mean ± S.E

		Transect I		Transect II	
Zone	Month	Cleared	Uncleared	Cleared	Uncleared
Salt Fan	July	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
	August	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
	October	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Salicornia	July	0.0 ± 0.0	2.0 ± 0.4	0.0 ± 0.0	2.0 ± 1.0
	August	0.0 ± 0.0	1.6 ± 0.2	0.0 ± 0.0	1.0 ± 0.5
	October	0.0 ± 0.0	0.6 ± 0.4	0.0 ± 0.0	1.0 ± 0.5
Atriplex	July	3.6 ± 0.9	4.4 ± 0.7	4.8 ± 1.2	9.4 ± 0.6
	August	3.6 ± 0.9	4.4 ± 0.7	3.4 ± 0.6	7.4 ± 0.9
	October	3.2 ± 0.5	4.4 ± 0.7	2.6 ± 0.8	7.4 ± 0.9
Hordeum	July	4.4 ± 0.9	6.4 ± 1.3	9.2 ± 0.4	9.0 ± 1.0
	August	3.2 ± 0.7	6.2 ± 1.2	8.6 ± 0.7	7.6 ± 1.4
	October	3.2 ± 0.7	6.2 ± 1.2	7.2 ± 1.3	7.6 ± 1.4
Meadow	July	5.0 ± 1.5	7.0 ± 1.3	5.2 ± 1.5	5.4 ± 1.5
	August	4.6 ± 1.2	6.2 ± 1.2	4.2 ± 1.6	5.4 ± 1.5
	October	4.0 ± 1.3	6.2 ± 1.2	4.2 ± 1.6	5.4 ± 1.5

Mortality of A. triangularis plants in different portions of a salinity gradient was found to occur at different times during the 1981 and 1982 growing seasons (fig. 3). In 1981, conditions were stable in terms of precipitation and soil salinity and only in the less saline sites 1 and 2 was mortality high early in the growing season. In 1982,



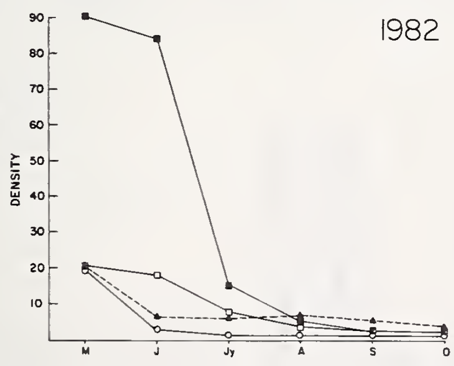


Figure 3.--Survival of Atriplex triangularis in 100 cm^2 quadrats during the 1981 and 1982 growing seasons. Quadrat 16-20 of Figure 1. 16 = open triangle, 17 = closed square, 18 = open square, 19 = open circle, and 20 = closed triangle.

the period of highest mortality was between the May and June measurements in the less saline sites and between the June and July measurements in the more saline sites 3 and 4 (fig. 3). The latter mortality was probably due to an increase in soil water potentials from -3.0 MPa to -5.9 MPa during this period in the high salt Atriplex zone. Mortality in the low salt zones was probably due to drought stress and the increased salinities induced by low precipitation during the early part of the growing season, when precipitation was 65 percent less than normal. Osmond and others (1980) found that plant establishment was related to the quantity and periodicity of precipitation. High summer precipitation favored establishment of A. vesicaria Heward and A. stipitata Benth.

Keddy (1981) has suggested a technique for determining whether differences in survivorship for populations of a species are due to density dependent or density independent factors. Applying this procedure in an attempt to interpret changes in field densities of A. triangularis indicates that the chief factors determining survival of plants are environmental. Survival was not closely related to maximal plant density as would be expected if density dependent factors were significant (fig. 4). Data were collected from 16 in.^{2} (100 cm^2) quadrats over a four year period. The linear regression Y = 26.0771-0.1196 X, has a regression coefficient which is not significantly different from 0 ($P<0.4$). The coefficient of determination, $r^2 = 0.0217$, explains only a very small portion of the variation in survival in relation to initial plant density. High plant density causes a decrease in plant size (Riehl and Ungar 1982, 1983). Small shallow root systems produced by smaller plants are more susceptible to salinity or drought stress which is most severe in the surface soils.

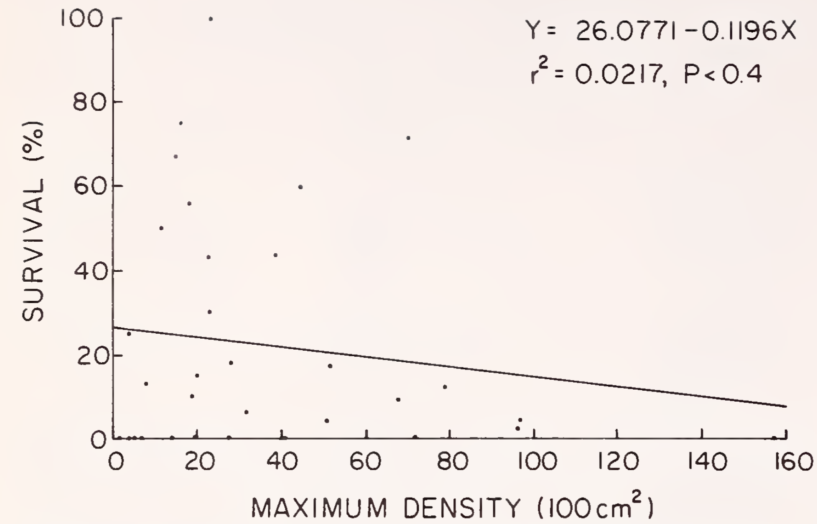


Figure 4.--The relationship between peak plant densities in 100 cm^2 quadrats and survival in Atriplex triangularis populations.

Very high salt stress appears to cause mortality at all plant densities.

SEED DIMORPHISM

Some plant species which grow in saline environments have developed seed dimorphism or polymorphism (Beadle 1952; Salisbury 1958; Konig 1960; Dalby 1962; Sterk 1969a,b; Drysdale 1973; Grouzis and others 1976; Ungar 1979, 1982). Seed polymorphism is a significant advantage to species growing in variable environments, because it provides alternate temporal and spatial germination situations. If there was only a single synchronized germination period in these highly variable environments and no seed reserve was available, an entire population of plants could be eliminated by increased salt stress during the growing season. We found that seeds of A. triangularis have an extended germination period, lasting from February to June, with some germination occurring even in late fall.[2] This pattern is most likely related to both the difference in physiological responses of dimorphic seeds and fluctuations in soil salinity during the growing season which limit the periods when seeds can germinate.

The presence of seed dimorphism in the genus Atriplex has been described for a number of species (Hall and Clements 1923; Beadle 1952; Frankton and Bassett 1968, 1970; Ungar 1971; Taschereau 1972). Nobs and Hagar (1974) found that large seeds of A. hortensis L. are produced earlier from flowers without a perianth but with bracteoles surrounding the fruit, while small seeds are produced later from flowers with a perianth but without bracteoles. Both large and small seeds of A. triangularis have bracteoles surrounding them when the fruit is mature (Ungar 1971). Beadle (1952) found that the ratio of small black to large brown seeds was variable in A. semibaccata F. Muell and A. inflata R. Br., ranging from 10:1 to 1.3:1 in the former and from 6:1 to 1:2.5 in the latter species. Drysdale (1973) reported that seed distribution in A. triangularis was log-normal, with a ratio of small to large seeds from 3:1 to 30:1, averaging 16:1 for the 46 plants observed. Further studies with A. triangularis under field and laboratory conditions indicate that plant size affects both the number of seeds produced $plant^{-1}$ and the ratio of small to large seeds (table 4).

Collections of seeds from A. triangularis plants in October, 1980, indicate a statistically significant relationship ($P<0.001$) between seed weight and seed size. The linear regression curves for plants in both high and low salt environments are similar: $Y = 1.70 + 1.87 X$ ($r^2 = 0.93$) for high salt, and $Y = 1.78 + 1.83 X$ ($r^2 = 0.92$) for low salt habitats. Figure 5 illustrates the differences in frequency of distribution of seeds in seed size classes of plants in both high salt and low salt environments. Plants in high salt environments had a greater number of seeds in the larger diameter size classes than did plants from low salt habitats. Osmond and others (1980) reported that the seed coat of large brown seeds of A. hortensis is more permeable to water because it has an outer layer of thin walled cells, while the small black seeds which have a less permeable seed coat have an outer layer of cylindrical sclereids. Water uptake by large brown seeds was more rapid than by the small black seeds (Nobs and Hagar 1974; Osmond and others 1980). A 0.5 M NaCl treatment limited water uptake to less than 50 percent of the distilled water control.

SEED BANK

The significance of seed banks in determining the establishment of plant communities on saline soils is not well understood. A survey of seed reserves in nonsaline soils from ten contrasting environments containing herbaceous vegetation indicated a general lack of correspondence between the flora of any single area and the species composition of its seed bank (Thompson and Grime 1979). Van der Valk and Davis (1976, 1978) and Keddy and Reznicek

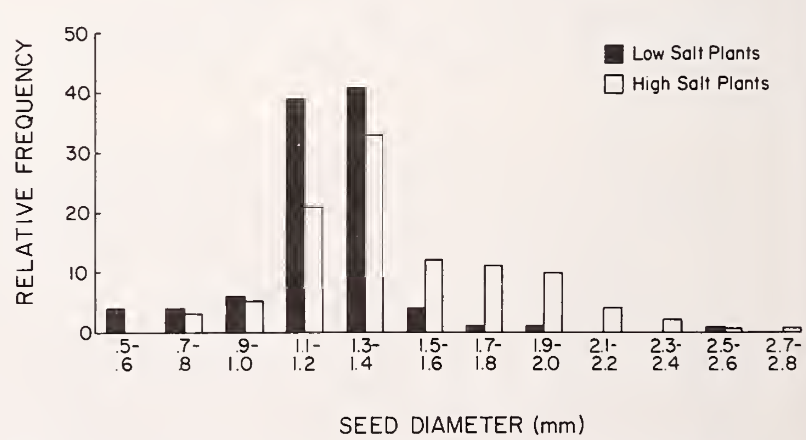


Figure 5.--Frequency of seeds in various size classes from Atriplex triangularis plants collected in low salt and high salt habitats.

[2] Ungar and Khan. Unpublished data, 1981.

(1982) concluded that the species composition of seed banks determined the nature of hydrarch succession in freshwater marshes. They found that seeds of all marsh species were dispersed into all of the vegetation zones. In contrast to these results, Leck and Graveline (1979) observed a correlation between the floral composition of a freshwater marsh and the makeup of its buried seed populations. They concluded that the seed bank was a good predictor of the plant communities in this New Jersey freshwater marsh. The quantitative nature of the seed bank also appears to vary from one year to the next. Young and others (1980) reported that seed banks had up to 300,000 seeds 10.8 ft.$^{-2}$ (m^{-2}) in wet years and 62,000 seeds 10.8 ft.$^{-2}$ (m^{-2}) during dry years in annual grssslands of California.

Milton (1939) found some variability in the relationship between the seed reserves in the soil and the actual species composition of halophyte communities. The seed bank of weed species growing at the margin of the salt marsh was larger than the actual presence of plants in marsh communities indicated. Several highly salt tolerant species were under-represented in the seed bank of these zonal saline communities. Jefferies and others (1981) in studies of Salicornia populations in coastal salt marshes reported that a persistent seed bank did not occur. Ungar and Riehl (1980) found that the three dominant halophytes along different portions of a salinity gradient, Hordeum jubatum, Atriplex triangularis, and Salicornia europaea were present in the seed banks of all zones. A glycophyte, Juncus tenuis, was the dominant in seed banks of spring collections from the Hordeum and Atriplex zones, even though no seedlings or mature individuals of this species were found growing in saline environments. The presence of these species with differing salt tolerance in all zones indicates that soil salinity is the primary factor controlling the distribution of plants along this gradient and that the species composition of these halophyte communities can change rapidly with changing soil conditions.

Atriplex triangularis seeds are polymorphic in size, producing a log normal distribution with more seeds in the small seed size classes .4 to .6 in. (1.0 to 1.5 mm) and fewer seeds in the large seed size classes .64 to 1.0 in. (1.6 to 2.6 mm) (Drysdale 1973). Soils were sifted through a 35 mesh, .2 in. (0.5 mm diameter) sieve to estimate the number of seeds in the soil. After seed fall in December there was an estimated 108,280 A. triangularis seeds 10.8 ft.$^{-2}$ (m^{-2}) in the seed bank, based on direct counts from soil samples (table 8). Following the normal February through May germination period, the surface soils (0 to 2 cm) were found to contain a mean number of 27,861 seeds 10.8 ft.$^{-2}$ (m^{-2}) in the seed bank from samples taken monthly from June to September 1981. Germinability of seeds collected from these monthly samples was high, averaging 76 percent throughout the year. The December and January collections containing a high proportion of fresh 1981 seeds averaged 73 percent germination, while seeds from the remaining months had an average

Table 8.--Mean number of A. triangularis seeds m^{-2} in monthly seed banks, 1981.

Month	Small seed	Large seed	Total
April	38,208	0	38,208
May	41,401	0	41,401
June	28,656	0	28,656
July	28,656	0	28,656
August	25,478	0	25,478
September	28,656	0	28,656
October	35,032	637	35,669
November	35,032	3,185	38,217
December	95,541	12,739	108,280

germinability of 83 percent. Even after the normal germination period, seeds collected in soil samples from June through November had 88 percent germination, indicating that seed viability remains high throughout the year. Roberts and Neilson (1980) found that Atriplex patula L. seeds could remain buried in soils for at least 5 years without losing their viability.

A study of seasonal change in the proportion of large and small seeds in the seed bank produced by A. triangularis during 1981 showed that no large seeds were stored in the soil from April to September (table 8). The number of large seeds in the surface soil increased from 637 to 12,379 seeds 10.8 ft.$^{-2}$ (m^{-2}) during the period of seed rain from October through December. Large seeds germinated early in the growing season and were not part of the permanent seed bank. These large seeds would be classified as a Type II transient seed bank (Thompson and Grime 1979) since they are produced in the fall and remain in the seed bank only over winter. The small seeds of A. triangularis provide a Type IV permanent seed bank in which seeds that are produced in the fall ordinarily do not germinate until the following spring and persist in the soil for more than one growing season. Beadle (1952) found that perennial species of Atriplex which produced only large brown seeds were being replaced by annuals that produced both seed types. He hypothesized that large brown seeds were short-lived while the small black seeds probably accumulated in the soil as a seed reserve until the testas become permeable. Our data with A. triangularis support this hypothesis since the small black seeds were the only size class to form a permanent seed bank.

GERMINATION

The effect of salinity stress on the physiology and ecology of germination of halophyte seeds has been reviewed recently by Ungar (1978, 1982). Two differences in the behavior of halophytes are apparent in comparison to glycophytes. First, seeds of salt tolerant plants are able to germinate at higher salinities than intolerant organisms, but they still respond with reduced final germination percentages and with delays in seed germination when their tolerance limits are

approached. Second, unlike salt intolerant species, seeds of many halophytic species are capable of remaining dormant under hypersaline conditions and then germinating when salinity levels are reduced.

Temperature and salinity interact in their effects on seed germination. Ward (1967) found that seeds of A. hastata L. s. sp. novae zelandiae Aellen were dormant, but that they responded to a cold pretreatment. Germination rates of up to 95 percent were obtained in salinities up to 1 percent NaCl. No germination was found at salinities of 2, 3, or 4 percent NaCl. Gustafsson (1973) concluded that seeds of A. triangularis lost their viability in storage at 15° C and 18° C, because he obtained only from 6 to 8 percent germination. We have found that A. triangularis seeds remain dormant at constant temperatures (10° C to 25° C). Low germination percentages of laboratory seeds may be due to some induced dormancy (Khan and Ungar, unpublished data). Gustafsson (1973) found that seeds stored outdoors averaged 70 percent germination. Scandinavian seed sources were able to withstand salinities of 3 and 6 percent total salts and then germinate at levels equal to those of seeds not exposed to salt stress (Gustafsson 1973). Seeds of A. vesicaria and A. nummularia Lindl. were inhibited by increments of NaCl ranging from -0.2 MPa to -2.2 MPa and a delay in germination was observed at the higher salinities (Sharma 1973).

There is some question concerning the significance of bracteoles in determining the germination behavior of Atriplex species (Beadle 1952; Kadman-Zahavi 1953; Koller 1957; Binet 1965; Ward 1967; Sankhary and Barbour 1972; Billard and Binet 1975; Osmond and others 1980). Beadle (1952) concluded that chloride accumulation in the bracteoles was the cause of germination inhibition. He found that the levels of chloride, reported as NaCl equivalents, in the bracteoles of five Australian species of Atriplex ranged from 0.44 M to 0.90 M NaCl. The germination of seeds in unsoaked fruits that were enclosed in bracteoles was reduced by 57 percent in A. vesicaria, 54 percent in A. inflata and 94 percent in A. spongiosa F. Muell. Others, including Kadman-Zahavi (1953), and Koller (1957), felt that Cl^- was not the cause of inhibition, but that some other unknown water soluble inhibitor was present in the bracts. Osmond and others (1980) hypothesized that several inches of precipitation would leach salt from the bracteoles and then permit germination. Ward (1967) found that seeds of A. hastata subsp. novae zealandieae were shed from bracteoles prior to germination. She suggested that the chief function of bracteoles was to enhance dispersal by providing greater surface area to facilitate floating. In A. triangularis the bracteoles may serve both to disperse seeds and prevent germination during late fall, but they are not an inhibitory factor during the normal spring germination period because the bracteoles are completely decomposed by this time. Another possible function of bracteoles, suggested by Cresswell and Grime (1981) is to induce a secondary dormancy in seeds through the phytochrome system, because their chlorophyll increases the ratio of far red to red illumination reaching the seeds.

Seeds of A. triangularis were collected from plants growing in high salt and low salt environments to determine if the salinity to which parent plants were exposed had an influence on seed germination. Seeds were obtained from plants growing on a salt pan at Rittman, Ohio, in October 1980, and germination studies were initiated in June 1982. Four 25 seed replicates were used for each experimental condition. Petri dishes containing small black seeds were placed in an incubator with a 12 h photoperiod, a 5° C night temperature, and a 25° C day temperature. In comparison to treatments ranging from 0 to 1 percent NaCl, a significant decrease in germination was observed in the 2 percent NaCl treatment from both of the seed sources. An even sharper decline in germination was found in the 3.0 percent NaCl treatment (table 9). High recovery germination percentages, equivalent to those of the original germination values in distilled water, were obtained when seeds originally germinated in 2, 3, and 4 percent NaCl were returned to distilled water. No significant differences were found in the germination responses of seeds from the two different seed sources when germinated at salinities ranging from 0 to 3 percent NaCl. Ignaciuk and Lee (1980) found that germination of A. glabriuscula Edmondst. and A. laciniata L. was not inhibited by salinities of 4 and 5 percent NaCl upon return to distilled water (Zid and Boukhris 1977). A second experiment with seeds from laboratory grown plants indicated, as in the case of the field plants, that the conditions in which parent plants were grown (nutrient solution plus 0 to 2 percent NaCl) had no effect on the salt tolerance of their seeds.

To determine if media salinity influences the salt content of seed, a measurement was made of the ionic content of seeds produced under different growth conditions. Salt contents of seeds were estimated from specific conductance measurements of aqueous extracts of dry seed. Potassium and sodium ion content was determined by flame emission with a Perkin-Elmer model 360 atomic absorption spectrophotometer. Chloride ion content was measured with a Beckman chloride specific ion electrode. Seeds of field grown plants had an average total salt content of 2.1 percent from the high salt environment and 1.7 percent total salts

Table 9.--Percentage germination of small black seeds of Atriplex triangularis from plants originally growing in high salt and low salt environments.

	NaCl (%)				
	0.0	0.5	1.0	2.0	3.0
High salt	99	92	86	52	0
Low salt	100	99	96	66	0

from the low salt environment. Seeds of laboratory grown plants contained 1 percent total salts in the nutrient solution control and averaged 2.3 percent in seeds from the 2.0 percent NaCl growth treatment (table 10). Plants evidently can control the amount of Na^+ and Cl^- transported to seeds since these elements are maintained at a lower concentration in the seeds than in shoots. Potassium ion content remained relatively constant in seeds from all treatments, while Na^+ and Cl^- tended to increase with increasing salt increments (table 10). Considering the fact that shoot ionic content reached 5.0 percent total salts in the low salt plants and 15.0 percent in the high salt plants, there is a definite inhibition of Na^+ and Cl^- ion transfer to seeds. Poulin and others (1978) found that Na^+ concentrations in seeds of Salicornia europaea collected from saline environments averaged 0.77 percent of the dry weight compared to from 8.0 to 14.8 percent Na^+ in plants at later stages of development. Seeds of Cakile maritima Scop. were found to have a Na^+ content of 0.02 percent and a chloride content of 0.07 percent compared to leaf Cl^- contents of 14.1 percent and Na^+ concentrations of 6.8 percent (Hocking 1982).

These data indicate that halophytes control the transport of ions to seeds, where the ionic content is generally lower than in other plant organs, and in this manner avoid injury from osmotic stress or specific ion-induced stress during the period of embryonic development.

SUMMARY

1. Soil water potentials averaging -1.5 MPa (about 2.0 percent total salts) and lower caused a sharp reduction in growth of both root and shoot systems of Atriplex triangularis. Plants could survive under hypersaline conditions by adjusting their water potential to that of the marsh soils, but soil water potentials between -2.0 and -5.0 MPa were responsible for high mortality.

Table 10.--Percentage of total ionic content of Atriplex triangularis seeds from both field and laboratory grown plants.

	Plant Origin					
	Laboratory				Field	
	Salt Content					
	0.0	0.5	1.0	2.0	1.0	2.7
Na^+	0.2	0.3	0.3	0.5	0.6	0.7
K^+	0.6	0.6	0.6	0.6	0.5	0.7
Cl^-	0.1	0.3	0.2	0.4	0.5	0.7
Total salts[1]	1.0	1.7	1.6	2.3	1.7	2.1

[1]Total salt content estimated from electrical conductivity measurements.

2. Field plants collected at the end of the growing season were found to have allocated from 25 to 37 percent of their biomass production to reproductive structures. A significant linear relationship, $r^2 = 0.87$, was determined between the dry weight production of plants and the number of seeds produced per individual plant. Factors such as high soil salinity, drought, and competition that reduce plant size were responsible for a corresponding reduction in seed production.

3. Transplants of plants into cleared and uncleared plots established in different vegetation zones indicate, by their growth responses, that interspecific competition caused a reduction in both root and shoot yields of A. triangularis. High soil salinities were inhibitory to both the establishment and growth of plants in the Pan Salicornia and Salicornia zones.

4. Thinning experiments under field conditions confirmed that the dry weight production of plants was closely correlated to initial plant densities. Biomass production of individual plants also influenced seed production; larger plants produced greater numbers of seeds than smaller plants.

5. Seed dimorphism in A. triangularis is an important factor affecting the time of seed germination, seed dispersal, and long term storage of seed in the seed bank. Small black seeds in this species are more dormant and form a permanent Type IV seed bank. Large brown seeds all germinate in the spring, and produce only a transient Type II seed reserve.

6. Seed germination was inhibited at salinity levels above 1 percent NaCl. No direct relationship could be ascertained between the germination response of seeds at any salinity level and salinity conditions of parent plants in both the field and laboratory.

7. The ionic content of seeds varied from that of nutrient solution controls containing 1 percent salts to that of laboratory grown plants at 2 percent NaCl + nutrients which had a total of 2.3 percent total salts. Similar values were obtained from high salt environments in the field where seeds had a total salt content of 2.1 percent. Increases in the total ionic content of seeds were mainly due to Na^+ and Cl^- ion accumulation, but these values were much lower than the 15 to 20 percent total ion content found in shoots.

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PUBLICATIONS CITED

Barbour, M. G. The effect of competition and salinity on the growth of a salt marsh plant species. Oecologia 37: 93-99; 1978.

Beadle, N. C. W. Studies in halophytes. I. The germination of the seed and establishment of the seedlings of five species of Atriplex in Australia. Ecology. 33: 49-62; 1952.

Billard, J. P.; Binet, P. Physio-écologie des Atriplex des milieux sableux littoraux. Bull. Soc. Bot. Fr. 122: 51-64; 1975.

Binet, P. Etude quelques aspects physiologique de la germination chez Atriplex tornabeni Tin. Bull. Soc. Nord Fr. 18: 40-55; 1965.

Binet, P. Action des complexes formes par les haut de plage et les dunes embryonnaires sur Atriplex babingtonii Woods. Oecol. Plant. 2: 63-78; 1967.

Binet, P.; Thammavong, B. Production primarire et accumulation des bioéléments au niveau d'une population pure d'Atriplex hastata L. des rives de l'estuaire de la Seine (France). Acta Oecologia, Oecol. Plant. 3(17): 219-230; 1982.

Black, R. F. Effect of NaCl in water culture on the ion uptake and growth of Atriplex hastata L. Aust. J. Biol. Sci. 9: 67-80; 1956.

Black, R. F. Effects of NaCl on the ion uptake and growth of Atriplex vesicaria Heward. Aust. J. Biol. Sci. 13: 249-266; 1960.

Branson, F. A.; Miller, R. F.; McQueen, I. S. Geographic distribution and factors affecting the distribution of salt desert shrubs in the United States. J. Range Manage. 20: 287-296; 1967.

Branson, F. A.; Miller, R. F.; McQueen, I. S. Plant communities and associated soil and water factors on shale-derived soils in northeastern Montana. Ecology. 51: 391-407; 1970.

Branson, F. A.; Miller, R. F.; McQueen, I. S. Moisture relationships in twelve northern desert shrub communities near Grand Junction, Colorado. Ecology. 57: 1104-1124; 1976.

Breckle, S-W. Zur Ökologie und zu den Mineralstoffverhältnissen absalzender und nichtabsalzender Xerohalophyten. Dissertationes Botanicae. 35: 1-169; 1976.

Chapman, V. J. Salt marshes and salt deserts of the world. Bremerhaven, West Germany: J. Cramer; 1974. 494 p.

Clarke, L. D.; Hannon, J. J. The mangrove swamp and salt marsh communities of the Sydney district. IV. The significance of species interaction. J. Ecol. 59: 535-553; 1971.

Cresswell, E. G.; Grime, J. P. Induction of a light requirement during seed development and its ecological consequences. Nature. 291: 583-585; 1981.

Dalby, D. H. Chromosome number, morphology and breeding behaviour in the British Salicorniae. Watsonia. 5: 150-162; 1962.

De Jong, T. M. Water and salinity relations of California beach species. J. Ecol. 67: 647-663; 1979.

Drysdale, F. R. Variation of seed size in Atriplex patula var hastata (L.) Gray. Rhodora. 75: 106-110; 1973.

Flowers, S. Vegetation of the Great Salt Lake region. Bot. Gaz. 95: 353-418; 1934.

Frankton, C.; Bassett, I. J. The genus Atriplex (Chenopodiaceae) in Canada. I. Three introduced species: A. heterosperma, A. oblongifolia, and A. hortensis. Can. J. Bot. 46: 1309-1313; 1968.

Frankton, C.; Bassett, I. J. The genus Atriplex (Chenopodiaceae) in Canada. II. Four native western annuals: A. argentea, A. truncata, A. powellii, and A. dioica. Can. J. Bot. 48: 981-989; 1970.

Gale, J.; Poljakoff-Mayber, A. Interrelations between growth and photosynthesis of salt bush (Atriplex halimus L.) grown in saline media. Aust. J. Biol. Sci. 23: 937-945; 1970.

Gale, J.; Naaman, R.; Poljakoff-Mayber, A. Growth of Atriplex halimus L. in sodium chloride salinated culture solutions as affected by the relative humidity of the air. Aust. J. Biol. Sci. 23: 947-952; 1970.

Gates, D. H.; Stoddart, L. A.; Cook, C. W. Soil as a factor influencing plant distribution on salt deserts of Utah. Ecol. Monogr. 26: 155-175; 1956.

Gray, A. J.; Scott, R. The ecology of Morecambe Bay. VII. The distribution of Puccinellia maritima, Festuca rubra and Agrostis stolonifera in the salt marshes. J. Appl. Ecol. 14: 229-241; 1977.

Greenway, H.; Gunn, A.; Thomas, D. A. Plant responses to saline substrates. VIII. Regulation of ion concentrations in salt-sensitive and halophytic species. Aust. J. Biol. Sci. 19: 741-756; 1966.

Grouzis, M.; Berger, A.; Heim, G. Polymorphisme et germination des graines chez espèces annuelles du genre Salicornia. Oecol. Plant. 11: 41-52; 1976.

Gustafsson, M. Evolutionary trends in the Atriplex triangularis group of Scandinavia. I. Hybrid sterility and chromosomal differentiation. Botaniska Notiser. 126: 345-392; 1973.

Hall, H. M.; Clements, F. E. The phylogenetic method in taxonomy: the North American species of Artemisia, Chrysothamnus, and Atriplex. Publication No. 326. Washington, D.C.: Carnegie Inst. of Washington; 1923. 355 p.

Harper, J. L. Population biology of plants. New York: Academic Press; 1977. 892 p.

Hocking, P. J. Salt and mineral nutrient levels in fruits of two strand species, Cakile maritima and Arctotheca populifolia, with special reference to the effect of salt on the germination of Cakile. Ann. Bot. 50: 335-343; 1982.

Ignaciuk, R.; Lee, J. A. The germination of four annual strand-line species. New Phytologist. 84: 581-591; 1980.

Jefferies, R. L.; Davy, A. J.; Rudmik, T. Population biology of the salt marsh annual Salicornia europaea agg. J. Ecol. 69: 17-31; 1981.

Kadman-Zahavi, A. Notes on the germination of Atriplex rosea. Bull. Res. Counc. Israel. 4: 375-378; 1955.

Keddy, P. A. Experimental demography of the sand-dune annual, Cakile edentula, growing along an environmental gradient in Nova Scotia. J. Ecol. 69: 615-630; 1981.

Keddy, P. A.; Reznicek, A. A. The role of seed banks in the persistence of Ontario's coastal plain flora. Am. J. Bot. 69: 13-22; 1982.

Kelley, D. B.; Goodin, J. R.; Miller, D. R. Biology of Atriplex. In: Sen, D. N.; Rajpurohit, K. S., eds. Contributions to the ecology of halophytes. The Hague: Dr. W. Junk Publishers; 1982: 79-107.

Koller, D. Germination regulating mechanisms in some desert seeds. IV. Atriplex dimorphostegia Kar. et Kir. Ecology. 38: 1-13; 1957.

König, D. Beiträge zur Kenntnis der deutschen Salicornien. Mitteilungen der Floristisch-soziologischen Arbeitsgemeinschaft. 8: 5-58; 1960.

Leck, M. A.; Graveline, K. J. The seed bank of a freshwater tidal marsh. Am. J. Bot. 66: 1006-1015; 1979.

Mahall, B. E.; Park, R. B. The ecotone between Spartina foliosa Trin. and Salicornia virginica L. in salt marshes of northern San Francisco Bay. II. Soil water and salinity. J. Ecol. 64: 793-809; 1976.

McMahon, K. A.; Ungar, I. A. Phenology, distribution and survival of Atriplex triangularis Willd. in an Ohio salt pan. Am. Midl. Nat. 100: 1-14; 1978.

McGraw, D. C.; Ungar, I. A. Growth and survival of the halophyte Salicornia europaea L. under saline field conditions. Ohio J. Sci. 81: 109-113; 1981.

Milton, W. E. J. The occurrence of buried viable seeds in soils at different elevations and on a salt marsh. J. Ecol. 27: 149-159; 1939.

Nobs, M. A.; Hagar, W. G. Analysis of germination and flowering rates of dimorphic seeds from Atriplex hortensis. Washington, D.C.: Carnegie Institution Year Book. 73: 859-864; 1974.

Osmond, C. B.; Björkman, O.; Anderson, D. J. Physiological processes in plant ecology. Berlin, West Germany: Springer-Verlag; 1980. 468 p.

Poulin, G.; Bourque, D.; Eid, S.; Jankowski, K. Composition chimique de Salicornia europaea L. Le Naturaliste Canadien. 105: 473-478; 1978.

Richardson, S. G.; McKell, C. M. Water relations of Atriplex canascens as affected by the salinity and moisture percentage of processed oil shale. Agron. J. 72: 946-950; 1980.

Riehl, T. E.; Ungar, I. A. Growth and ion accumulation in Salicornia europaea under saline field conditions. Oecologia. 54: 193-199; 1982.

Riehl, T. E.; Ungar, I. A. Growth, water potential and ion accumulation in the inland halophyte Atriplex triangularis under saline field conditions. Acta Oecologia, Oecol. Plant. 4(18): 27-39; 1983.

Roberts, H. A.; Neilson, J. E. Seed survival and periodicity of seedling emergence in some species of Atriplex, Chenopodium, Polygonum and Rumex. Ann. Appl. Biol. 94: 111-120; 1980.

Sankary, M. N.; Barbour, M. G. Autecology of Atriplex polycarpa from California. Ecology. 53: 1155-1162; 1972.

Sharma, M. L. Simulation of drought and its effect on germination of five pasture species. Agron. J. 65: 982-987; 1973.

Sharma, M. L. Aspects of salinity and water relations of Australian chenopods. In: Sen, D. N.; Rajpurohit, K. S., eds. Contributions to the ecology of halophytes. The Hague: Dr. W. Junk Publishers; 1982: 155-172.

Sharma, M. L.; Tunny, J; Tongway, D. J. Seasonal changes in sodium and chloride concentrations of salt bush (Atriplex spp.) leaves as related to soil and plant water potential. Aust. J. Agric. Res. 23: 1007-1019; 1972.

Sterk, A. A. Biosystematic studies of Spergularia media and S. marina in the Netherlands. I. The morphological variability of S. media. Acta Botanica Neerlandica. 18: 325-338; 1969a.

Sterk, A. A. Biosystematic studies on Spergularia media and S. marina in the Netherlands. III. The variability of S. media and S. marina in relation to the environment. Acta Botanica Neerlandica. 18: 561-577; 1969b.

Storey, R.; Wyn Jones, R. J. Responses of Atriplex spongiosa and Suaeda monoica to salinity. Plant Phys. 63: 156-162; 1979.

Suehiro, K.; Ogawa, H. Competition between two annual herbs, Atriplex gmelini C.A. Mey and Chenopodium album L., in mixed cultures irrigated with seawater of various concentrations. Oecologia. 45: 167-177; 1980.

Szwarcbaum, I., Waisel, Y. Inter-relationships between halophytes and glycophytes grown on saline and non-saline media. J. Ecol. 61: 775-786; 1973.

Taschereau, P. M. Taxonomy and distribution of Atriplex species in Nova Scotia. Can. J. Bot. 50: 1571-1594; 1972.

Thompson, K.; Grime, J. P. Seasonal variation in the seed banks of herbaceous species in ten contrasting habitats. J. Ecol. 67: 893-921; 1979.

Ungar, I. A. Atriplex patula var. hastata seed dimorphism. Rhodora. 73: 548-551; 1971.

Ungar, I. A. The vegetation of inland saline marshes of North America, north of Mexico. In: Tuxen, R., ed. Grundfragen und methoden in der pflanzensoziologie. The Hague: Dr. W. Junk Publishers; 1972: 397-411.

Ungar, I. A. Inland halophytes of the United States. In: Reimold, R. J.; Queen, W. H., eds. Ecology of halophytes. New York: Academic Press; 1974: 235-305.

Ungar, I. A. The relationship between soil water potential and plant water potential in two inland halophytes under field conditions. Bot. Gaz. 138: 498-501; 1977.

Ungar, I. A. Halophyte seed germination. Bot. Rev. 44: 233-264; 1978.

Ungar, I. A. Seed dimorphism in Salicornia europaea. Bot. Gaz. 140: 102-108; 1979.

Ungar, I. A. Germination ecology of halophytes. In: Sen, D. N.; Rajpurohit, K. S., eds. Contributions to the ecology of halophytes. The Hague: Dr. W. Junk Publishers; 1982: 143-154.

Ungar, I. A.; Benner, D. K.; McGraw, D. C. The distribution and growth of Salicornia europaea on an inland salt pan. Ecology. 60: 329-336; 1979.

Ungar, I. A.; Riehl, T. E. The effect of seed reserves on species composition in zonal halophyte communities. Bot. Gaz. 141: 447-452; 1980.

Van der Valk, A. G.; Davis, C. B. The seed banks of prairie glacial marshes. Can. J. Bot. 54: 1832-1838; 1976.

Van der Valk, A. G.; Davis, C. B. The role of seed banks in the vegetation dynamics of prairie glacial marshes. Ecology. 59: 322-335; 1978.

Vince, S. W. Vegetation patterns in an Alaskan salt marsh. Ann Arbor, MI: University of Michigan, School of Natural Resources News, 22: 14-17; 1981.

Waisel, Y. Biology of halophytes. New York: Academic Press 1972. 395 p.

Ward, J. M. Studies in ecology on a shell barrier beach. Section III. Chemical factors of the environment. Vegetatio. 15: 77-112; 1967.

Watkinson, A. R. Factors affecting the density response of Vulpia fasciculata. J. Ecol. 70: 149-161; 1982.

Wilson, D. B. Growth of Hordeum jubatum under soil conditions and degrees of plant competition. Can. J. Plant Sci. 47: 405-412; 1967.

Young, J. A.; Evans, R. A.; Raguse, C. A.; Larson, J. R. Germinable seeds and periodicity of germination in annual grasslands. Hilgardia. 49: 1-37; 1981.

Zedler, J. B. Salt marsh community structure in Tijuana estuary, California. Estuarine and Coastal Marine Sci. 5: 39-53; 1977.

Zid, E.; Boukhris, M. Quelques aspects de la tolérance d l' Atriplex halimus L. au chlorure de sodium, multiplication, croissance, composition minérale. Oecol. Plant. 12: 351-362; 1977.

In: Tiedemann, Arthur R.; McArthur, E. Durant; Stutz, Howard C.; Stevens, Richard; Johnson, Kendall L., compilers. Proceedings--symposium on the biology of Atriplex and related chenopods; 1983 May 2-6; Provo, UT. General Technical Report INT-172. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 309 p.

NATURAL GROWTH OF ATRIPLEX SUCKLEYI ((Torrey) Rydb.) ON BENTONITE MINE SPOILS IN SOUTHEASTERN MONTANA

Carolyn Hull Sieg, Daniel W. Uresk, and Richard M. Hansen

ABSTRACT: Rillscale (Atriplex suckleyi (Torrey) Rydb.) was the most common and productive plant on bentonite mine spoils, comprising between 40 and 94 percent of the total plant canopy cover and standing crop on the mine spoils; yet, it was uncommon on the unmined sagebrush-grass sites. The success of rillscale on the mine spoils was attributed to its adaptation to the climatic and edaphic conditions of the area, an adequate seed source, and the absence (or near absence) of competing vegetation. Soil compaction, high sodium concentrations, and acidic soils limited growth of rillscale on some mine sites.

INTRODUCTION

Rillscale (Atriplex suckleyi (Torrey) Rydb.) is an annual chenopodiaceous plant limited to the Great Plains of North America (McNeill and others 1979). It occurs in Alberta and Saskatchewan, Canada, and in Montana, Wyoming, North Dakota, South Dakota, and Nebraska in the United States (Frankton and Bassett 1970). Also known as scurfless saltbush, and previously named A. dioica (Nutt.) Macbride (Frankton and Bassett 1970), rillscale is limited to alkaline or badland sites (Hitchcock and Cronquist 1973), and is a common plant on bentonite mine spoils in Montana, Wyoming, and South Dakota. This study was designed to sample the plant canopy cover and standing crop of rillscale on bentonite mine spoils and sagebrush-grass rangeland in southeastern Montana, and to identify soil and other environmental characteristics which limit its establishment.

STUDY AREA

This study was conducted in extreme southeastern Montana, approximately 6 miles (9 km) west of the town of Alzada. The study area was on a dense clay-clayey-saline upland range site complex, as defined by Ross and Hunter (1976), at an elevation of approximately 3,300 to 3,600 ft (1000-1100 m). Annual average precipitation is 15 inches (37 cm), most of which falls between May and July (U.S. Department of Transportation, National Oceanic and Atmospheric Administration 1976). In 1979 and 1980, 10 and 14 inches (26 and 35 cm) of precipitation fell, respectively. The May to July precipitation for 1979 was 6 inches (15 cm), while only 4 inches (11 cm) fell during this period in 1980. Vegetation consists mainly of big sagebrush (Artemisia tridentata Nutt.) with an understory of western wheatgrass (Agropyron smithii Rydb.), blue grama (Bouteloua gracilis (H.B.K.) Steud.), and buffalograss (Buchloe dactyloides (Nutt.) Engelm.). Vegetation on bentonite mine spoils in the study area is dominated by rillscale (Sieg and others 1983).

METHODS

Twelve study sites were selected: ten on bentonite mine spoils resulting from mining activities between 1952 and 1978, and two on adjacent, unmined rangeland. The study sites were classified into four types: (1) old mine spoils; (2) reclaimed spoils; (3) semireclaimed spoils; and (4) sagebrush-grass rangelands. Five sites were established on old spoils (predating reclamation laws), which were 12 to 28 years old, steep, and nearly devoid of vegetation. Three sites were established on 5- to 12-year-old reclaimed spoils, which had been recontoured, spread with topsoil and seeded with a mixture of wheatgrasses (Agropyron spp.) and yellow sweetclover (Melilotus officinalis(L.) Lam.). Two sites were established on semireclaimed spoil piles, which were the result of mining the previous fall. One of the semireclaimed spoils was seeded with wheatgrasses and yellow sweetclover during the fall of the first year of the study. The steep grade of the other pile prevented seeding. Two sites were established on gently undulating unmined sagebrush-grass rangeland. All sites were accessible to sheep and cattle.

Plant canopy cover and standing crop were sampled on the 12 sites on a regular basis for 2 years. Plant canopy cover was estimated in June, July, and August each year in 150, 1.1-ft^2 (0.1-m^2) quadrats, spaced at 3.3-ft (1-m) intervals, along three permanent 164-ft (50-m) transects on each site (Daubenmire 1959). Canopy cover was visually estimated by seven cover classes: 0 = less than 1 percent cover, 1 = 1 to 5 percent, 2 = 5 to 25 percent, 3 = 25 to 50 percent,

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4 = 50 to 75 percent, 5 = 75 to 95 percent, and 6 = 95 to 100 percent cover.

Plant standing crop was estimated by harvesting plants at ground level annually, at peak production (late July), on all sites. At each site, plants were clipped in ten 8-inch X 20-inch (20-cm X 50-cm) quadrats, on each of three permanent transects, were ovendried in the laboratory at 140° F (60° C) for 48 hours, and were weighed.

Twenty soil samples were taken on each site during the second year, to a depth of 4 inches (10 cm), with a 2-inch (5-cm) soil probe mounted on a drill truck. A grid pattern with 49-ft (15-m) spacing was used to distribute the samples throughout the sites. Four composite subsamples were analyzed from each site: two from the first 10 samples, and two from the next 10 samples. Available levels of sodium and pH were analyzed by standard techniques (United States Salinity Laboratory Staff 1954).

Soil compaction was measured with a hand-held penetrometer scaled from 0 to 4.5 ton/ft^2 (0-4.5kg/cm^2). The load required to read 4.5 ton/ft^2 (4.5kg/cm^2) was 17 lb (7.7 kg). Twelve measurements were taken in a grid pattern with 46-ft (14-m) spacing, on each site, every 3 weeks from May to October, during the second year of the study, for a total of 96 measurements per site.

Analysis of variance and Tukey's multiple comparison procedure (Kleinbaum and Kupper 1978) were used to compare plant canopy cover, average aboveground biomass, and soil properties among site types, months, and years. Regression analyses were used to compare peak standing crop and plant canopy cover of rillscale to soil characteristics.

RESULTS

Plant Canopy Cover

The plant canopy cover of rillscale ranged from 1 to 8 percent on the mine spoils, and rillscale comprised between 40 and 94 percent of the total cover on these sites (table 1). Yet, rillscale was nearly absent on the sagebrush-grasslands. The cover of rillscale did not differ significantly ($P > 0.1$) from month to month, yet it varied ($P < 0.05$) between years. In 1979, the cover of rillscale was higher ($P < 0.05$) on reclaimed spoils than other sites, and was similar ($P > 0.1$) on semi-reclaimed spoils, old spoils, and sagebrush-grass rangelands. However, in 1980, canopy cover of this pioneer plant increased ($P < 0.001$) on semireclaimed spoils and decreased ($P < 0.05$) on other spoils. This resulted in similar cover values on the mine spoils, but higher ($P < 0.05$) cover values on these sites than on the sagebrush-grasslands. Plant canopy cover of rillscale on bentonite mine spoils was negatively correlated with penetrometer readings ($r = -0.52$, $P = 0.001$) and sodium concentrations ($r = -0.57$, $P = 0.001$), and positively correlated with pH ($r = 0.26$, $P = 0.1$).

Plant Standing Crop

Plant standing crop of rillscale ranged from less than 3 lb/acre (3 kg/ha) to 169 lb/acre (190 kg/ha), and accounted for 40 to 93 percent of the total standing crop on the mine spoils; whereas rillscale comprised only a small portion (<1 percent) of the standing crop on sagebrush-grasslands (table 2). In 1979, standing crop of rillscale was higher ($P < 0.05$) on reclaimed spoils (averaging 138 lb/acre (155 kg/ha) than on other sites, and did not differ ($P > 0.1$) on old spoils,

Table 1.--Range and average percent plant canopy cover of rillscale and percent of total plant cover on bentonite mine spoils and sagebrush-grass rangelands near Alzada, Mont., in 1979 and 1980.

	1979			1980		
	Percent canopy cover		Percent of	Percent canopy cover		Percent of
Site type	Range	$\bar{x}$	total cover	Range	$\bar{x}$	total cover
Old spoils	<1-6	2.6^1	68	<1-4	1.8^2	72
Reclaimed spoils	8-9	8.3^2	60	3-5	3.6^2	40
Semireclaimed spoils	<1	$<1^1$	46	3-7	4.9^2	94
Sagebrush-grasslands	<1	$<1^1$	<1	<1	$<1^1$	<1

[1,2]Means followed by the same letter superscript (within years) were not significantly different ($P > 0.05$).

semireclaimed spoils, and sagebrush-grasslands. However, in 1980, the standing crop of rillscale decreased ($P < 0.05$) on reclaimed and old spoils and increased ($P < 0.01$) on semireclaimed spoils. In 1980, the standing crop of rillscale was higher ($P < 0.1$) on semireclaimed spoils than on other sites, was higher ($P < 0.05$) on reclaimed spoils than on old spoils or sagebrush-grasslands, and was similar ($P > 0.1$) on old spoils and sagebrush-grass sites. Plant standing crop of rillscale on the bentonite mine spoils was negatively correlated with penetrometer readings ($r = -0.29$, $P = 0.07$) and sodium concentration ($r = -0.55$, $P = 0.001$), and positively correlated with pH ($r = 0.46$, $P = 0.003$).

Soils

Soils characteristics were highly variable on the bentonite mine spoils. In general, acidic pH values, high sodium concentrations, and compaction were common. More than 50 percent of the pH readings on old mine spoils were moderately to strongly acidic (table 3). Eight percent of the readings on reclaimed spoils were strongly acidic (pH 4.0 to 4.9), while pH values on semireclaimed spoils and sagebrush-grasslands were all slightly acidic (pH 6.0 to 6.9) to slightly alkaline (pH 7.0 to 7.9).

Sodium concentrations also were highly variable. Average concentrations on old spoils ranged from less than 2,000 ppm (10 percent of the samples) to more than 7,000 ppm (35 percent of the samples) (table 4). Average sodium concentrations on the reclaimed spoils were all less than 4,600 ppm, while 63 percent of the samples from semireclaimed spoils averaged between 4,600 and 6,900 ppm. Eighty-eight percent of the samples from sagebrush-grass rangelands contained sodium levels of less than 2,000 ppm (table 4).

Between 31 and 53 percent of the penetrometer readings on bentonite spoils averaged between 4.0 and maximum reading (4.5 ton/ft^2). Only 7 percent of the readings on the sagebrush-grasslands averaged above 4.0 (table 5). The majority of the penetrometer readings on the sagebrush-grass rangelands averaged less than 2.0, while fewer than one-third of the readings on the bentonite spoils averaged less than 2.0.

DISCUSSION

Bentonite mining activities and resultant spoil piles in southeastern Montana provided environments suitable for the establishment of rillscale. The presence and dominance of rillscale on bentonite mine spoils demonstrated the ability of this plant to rapidly colonize barren sites. The success of rillscale on the mine spoils (as plant cover and standing crop), when compared to seeded species or other native plants, was attributed to its adaptation to the climatic and edaphic conditions of the area, the absence (or near absence) of competitive vegetation, and an adequate seed source. The most inhibiting feature of the sagebrush-grasslands for the growth of rillscale was competition from other plants. The few rillscale plants observed on the sagebrush-grassland communities were limited to barren microsites.

The negative correlations of the cover and production of rillscale with penetrometer readings and sodium concentrations and positive correlation with pH indicate that certain soil (or spoil) characteristics are inhibiting to the growth of rillscale on bentonite mine spoils. With increasing compaction, excessive sodium concentration, and low pH, rillscale is less likely to grow. High compaction lessens the likelihood that plant roots will be able to

Table 2.--Range and average plant standing crop of rillscale, and percent of total standing crop on bentonite mine spoils and sagebrush-grass rangelands near Alzada, Mont., 1979 and 1980

Site type	1979 Plant standing crop (lb/acre) Range	1979 $\bar{x}$	1979 Percent of total crop	1980 Plant standing crop (lb/acre) Range	1980 $\bar{x}$	1980 Percent of total crop
Old spoils	3-65	29^1	57	0-55	19^1	40
Reclaimed spoils	117-169	138^2	50	54-79	68^2	51
Semireclaimed spoils	10-21	16^1	49	101-140	120^3	93
Sagebrush-grasslands	0-3	2^1	<1	0-2	1^1	<1

^{1,2,3}Means followed by the same letter superscript (within years) were not significantly different ($P > 0.05$).

Table 3.--Classification of soil samples (0-4 inches) taken on bentonite mine spoils and sagebrush-grasslands near Alzada, Mont., according to pH.

Classification	pH	Percent of samples: Bentonite mine spoils: Old	Reclaimed	Semireclaimed	Sagebrush-grasslands
Strongly acidic	(4.0 - 4.9)	45	8	0	0
Moderately acidic	(5.0 - 5.9)	15	0	0	0
Slightly acidic	(6.0 - 6.9)	25	33	63	25
Slightly alkaline	(7.0 - 7.9)	15	59	37	75

Table 4.--Distribution of soluble and exchangeable sodium concentrations in soil samples (0-4 inches) taken on bentonite mine spoils and sagebrush-grass rangelands near Alzada, Mont.

Na concentration (ppm)	Percent of samples: Bentonite mine spoils: Old	Reclaimed	Semireclaimed	Sagebrush-grasslands
0 - 2,000	10	33	0	88
2,000 - 4,600	40	67	37	12
4,700 - 6,900	10	0	63	0
> 7,000	40	0	0	0

Table 5.--Distribution of penetrometer readings taken on bentonite mine spoils and sagebrush-grass rangelands near Alzada, Mont.

Penetrometer reading (ton/ft^2)	Percent of samples: Bentonite mine spoils: Old	Reclaimed	Semireclaimed	Sagebrush-grasslands
0 to 0.9	4	5	2	39
1 to 1.9	11	20	19	28
2 to 2.9	13	17	30	18
3 to 3.9	19	20	18	8
4 to 4.5	53	38	31	7

penetrate the substrate. However, halophytic plants such as rillscale generally can become established in high-sodium media. Sodium concentrations on some of the mine spoils are apparently towards the upper range of tolerance for this plant. Further, rillscale appears to be more highly adapted to neutral or slightly alkaline soils, and is less tolerant of acidity. Low pH values are caused by the formation of sulfuric acid from inherent sulfate ions which neutralizes the alkaline effects of the spoil (Bjugstad and others 1981).

The combination of these factors may explain the lower cover (in 1979) and production (in both years) of rillscale on old spoils, compared to reclaimed spoils. High penetrometer readings, high sodium concentrations, and low pH were very common on old spoils, and comparatively less common on reclaimed spoils. Despite the near absence of competition from other plants on the old spoils, rillscale was inhibited by adverse spoil characteristics.

Differences in the plant cover and production of rillscale on semireclaimed spoils are more difficult to explain. The 1979 data were collected the first growing season after the spoils materials were recontoured and spread with topsoil. The low cover and standing crop of rillscale on semireclaimed spoils in 1979 suggest that at least one growing season is required for the accumulation of rillscale seeds to a level where this plant becomes an important component of the plant community. The flourish of rillscale the second year after reclamation may be interpreted as evidence of an adequate seed source, acceptable soil conditions, and very little competition from other plants. Acidic pH readings were not detected on the semireclaimed spoils, and these spoils were not as compacted as old spoils. Although most samples registered between 4,700 and 6,900 ppm of soluble and exchangeable sodium, none of the samples registered above 7,000 ppm. (Forty percent of the samples on old spoils were above 7,000 ppm.) Plant competition was unlikely on the semireclaimed spoils, because rillscale accounted for over 90 percent of the cover and production on these sites in 1980.

The decline in the plant canopy cover and standing crop of rillscale on reclaimed and old spoils in 1980, contrasted to the dramatic increase on semireclaimed spoils, indicated that the growing environments on old and reclaimed spoils have characteristics nearing the tolerance limits of rillscale, and that when this plant is stressed by drought, it is less likely to grow. The inhibiting feature for rillscale on reclaimed spoils, as compared to semireclaimed spoils, was likely competition from other plant species and possibly a few microsites of acidic soils. Otherwise, penetrometer readings were comparable on both reclaimed and semireclaimed spoils, and neither site type had sodium concentrations greater than 7,000 ppm. Greater soil compaction, higher sodium concentrations, and more acidic pH were inhibiting features for the growth of rillscale on old bentonite mine spoils when compared to semireclaimed spoils. These factors, coupled with drought in 1980, resulted in lower production of rillscale on the old spoils.

This study demonstrated that rillscale, a native annual forb, is highly adapted to bentonite mine spoil environments in south-eastern Montana. However, the standing crop and plant canopy cover of rillscale are limited by excessive soil compaction, high sodium concentrations, and acidic soils on some sites, particularly in combination with low precipitation. In general, reclaimed spoils provided better growing media for the establishment of rillscale than unreclaimed spoils, in the absence (or near absence) of competitive vegetation.

PUBLICATIONS CITED

Bjustad, Ardell J.; Yamamoto, Teruo; Uresk, Daniel W. Shrub establishment on coal and bentonite clay mine spoils. In: Proceedings, shrub establishment on disturbed arid and semi-arid lands symposium; 1980 December 2-3; Laramie, WY. Wyoming Game and Fish Department, Cheyenne, WY. 1981: 104-122.

Daubenmire, R. A canopy-coverage method of vegetational analysis. Northwest Sci. 33(1): 43-64; 1959.

Frankton, C.; Bassett, I. J. The genus Atriplex (Chenopodiaceae) in Canada. II. Four native western annuals: A. argentea, A. truncata, A. powelli, and A. diocia. Can. J. Bot. 48: 981-989; 1970.

Hitchcock, C. L.; Cronquist, A. Flora of the Pacific Northwest. Seattle, WA: University of Washington Press; 1973. 730 p.

Kleinbaum, D. G.; Kupper, L. L. Applied regression analysis and other multivariable methods. North Scituate, MA: Duxburg Press; 1978. 556 p.

McNeill, J.; Bassett, I. J.; Crompton, C. W. Atriplex suckleyi (Torrey) Rydb., the correct name for A. dioica (Nutt.) MacBride. Taxon. 28: 588-590; 1979.

Ross, R. L.; Hunter, H. E. Climax vegetation of Montana. Bozeman, MT: U.S. Department of Agriculture, Soil Conservation Service; 1976. 64 p.

Sieg, Carolyn Hull; Uresk, Daniel W.; Hansen, Richard M. Plant-soil relationship on bentonite mine spoils and sagebrush-grassland in the northern High Plains. J. Range Manage. 37: 289-294; 1983.

U.S. Department of Transportation, National Oceanic and Atmospheric Administration. Climate of Colony, Wyoming. Climatography of the United States No. 20. Asheville, NC: U.S. Department of Transportation, National Oceanographic and Atmospheric Administration; 1976. 4 p.

United States Salinity Laboratory Staff. Diagnosis and improvement of saline and alkali soils. Agric. Handb. 60. Washington, DC: U.S. Department of Agriculture; 1954. 160 p.

In: Tiedemann, Arthur R.; McArthur, E. Durant; Stutz, Howard C.; Stevens, Richard; Johnson, Kendall L., compilers. Proceedings--symposium on the biology of Atriplex and related chenopods; 1983 May 2-6; Provo, UT. General Technical Report INT-172. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 309 p.

WINTER HARDINESS AND JACKRABBIT PREFERENCE IN A

HYBRID POPULATION OF FOURWING SALTBUSH (ATRIPLEX CANESCENS)

James A. Young, Burgess L. Kay, and Raymond A. Evans

ABSTRACT: Populations of a natural hybrid of fourwing saltbush (Atriplex canescens) were planted in nurseries in northwestern Nevada and at two locations in the Mojave Desert in California. The parent populations differed in height growth, winter hardiness, and browsing preference by jackrabbits. The F_1 population was winter hardy and relatively resistant to browsing damage by jackrabbits. The apparently heritable variability demonstrated in the populations suggests the possibility of plant improvement through hybridization and selection.

INTRODUCTION

Fourwing saltbush (Atriplex canescens [Pursh] Nutt.) is one of the most widely distributed species of saltbush found on western North America rangelands (Dayton 1931). As early as 1900, fourwing saltbush was considered a valuable species for seeding on depleted rangelands (Smith 1900).

Springfield (1970) and Van Epps (1975) reported that collections of fourwing saltbush from different geographic areas were highly variable in several characteristics and that these characteristics were related to seed germination and seedling establishment. In a recent study, McArthur and others (1983) evaluated a broad spectrum of fourwing saltbush accessions at two common garden sites in Utah. They enumerated considerable variability in growth rate and growth form of the shrubs. Van Epps (1975) reported difficulty in establishing in cold environments plants of fourwing saltbush collected from relatively warm environments (e.g., plants from New Mexico planted in nurseries in northern Utah). Nord and Stallings (1975) reported that there was great variation in the browsing preferences exhibited by rabbits (presumed to be blacktailed jackrabbits (Lepus californicus)) to different collections of fourwing saltbush.

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Our purpose was to evaluate the winter hardiness and preference of jackrabbits for plants of a hybrid population of fourwing saltbush.

METHODS AND MATERIALS

In 1972, we transplanted fourwing saltbush plants grown from seed collected at three locations to a garden located at Granite Peak, some 21 miles (35 km) north of Reno, Nevada. The garden, at 5,900 feet (1 800 m) elevation, is a site that originally supported a mountain big sagebrush (Artemisia tridentata Nutt. ssp. vaseyana (Rydb.) Beetle)/Thurber needlegrass (Stipa thurberiana Piper) plant community. Average annual precipitation for the past 14 years has been 13 inches (32.5 cm). The soils of the garden are Typic Haplargids.

The sources of the seeds were: (a) 20 miles (34 km) north of Mojave, Calif., on Highway 14, elevation 2,950 feet (900 m); (b) 9 miles (15 km) north of Mojave, Calif., on State Highway 58, elevation 3,900 feet (1 200 m); and (c) near Nixon, Washoe County, Nev., elevation 3,900 feet (1 200 m).

The plants were grown for 1 year in 6 inch (15 cm) pots in a greenhouse and lath house before transplanting. The plants were planted on 39 inch (1 m) centers with 36 plants in a block for each of the sources. The blocks were separated by 39 inch (1 m) alleys. Fourwing saltbush does not occur naturally in the area.

All plants were transplanted during the summer of 1972 and were a uniform 24 inches (60 cm) in height by October. The plants of the two California sources appeared to renew growth in October 1972 after the first effective fall precipitation. In early December 1972, temperature dropped to 23°F (-5°C) for three consecutive nights at the Reno, Nev., weather reporting station. We did not have temperature recording equipment at Granite Peak, but subsequent monitoring of winter temperatures on the site indicated that nighttime minimums average 9° to 14°F (5° to 8°C) colder than Reno[1]. This particularly cold December apparently affected Atriplex canescens populations in many parts of the Great Basin (McArthur 1977).

[1]Unpublished data available from the Agricultural Research Service, Reno, Nev.

The Washoe County fourwing saltbush plants dropped all their leaves after the cold nights. Leaves on plants of the two California sources shrivelled, but initially remained on the plants. In the spring of 1973, all of the Nevada fourwing saltbush plants resumed growth. All of the low-elevation saltbush plants from California were dead. Only two of the higher elevation California plants survived the winter. All of the surviving fourwing saltbush plants flowered profusely in 1973. The surviving plants from the California source were both pistillate. Seeds collected from the two pistillate plants were used in various experiments over the next 9 years (fig. 1).

The abundant seeds (F_1) produced in 1973 were cold-moist stratified at 35°F (2°C) for 4 weeks and then planted in the greenhouse. The resulting seedlings were transplanted into a large block of 150 plants on 39 inch (1 m) centers at Granite Peak. Into this garden we also transplanted plants grown from seed obtained at the Washoe County, Nev., collection site of the staminate parent plants. The seeds produced by these hybrid plants (F_2) were collected in 1975. The seedlings from the hybrid plants were transplanted to Churchill Canyon, Nev., and to Granite Peak in 1975.

Churchill Canyon is located about 11 miles (18 km) northwest of Yerington, Nev., at 4,660 feet (1 420 m) elevation. Annual precipitation is estimated at 6 inches (15 cm) (Blackburn and others 1969). Soils on the garden site are Typic Camborthids. This is a very xeric site that naturally supports a basin big sagebrush (Artemisia tridentata ssp. tridentata Nutt.)/Nevada ephedra (Ephedra nevadensis Wats.) plant community (Young and Evans 1973).

At the Churchill Canyon plot, we transplanted plants of both parent collections (Mojave and Washoe) obtained from remnant seed and F_1 seed obtained from the same pistillate plants at Granite Peak the previous season. In addition, we included plants of the diploid or gigas form of fourwing saltbush (Stutz and others 1975) grown from seed obtained from the Intermountain Forest and Range Experiment Station, USDA Forest Service.

We collected seed in 1975 from the F_1 plants planted at Granite Peak in 1974 and repeated the plantings at Granite Peak and Churchill Canyon. In 1976, seed collected from the F_1 plants at Granite Peak was used to establish a garden at the Gund Research and Demonstration Ranch, Grass Valley, Nev.

The Gund Ranch garden is located on an alluvial fan at 5,440 feet (1 660 m) elevation. The site supports a Wyoming big sagebrush (Artemisia tridentata ssp. wyomingensis (Rydb.) Beetle and Young)/cheatgrass (Bromus tectorum L.) community (Young and Evans 1980). Annual precipitation was estimated at 8 inches (20 cm). Soils of the site belong to the Xerollic Haplargids subgroup.

Seeds collected from the F_1 plants at Granite Peak, plus seeds of the parents, were used to grow plants that were transplanted back to Granite Peak and to two locations in the Mojave Desert in 1980. The Mojave locations were 3 miles (5 km) west of Ridgecrest 3,340 feet (1 020 m) and 6 miles (10 km) north of Mojave 3,200 feet (975 m), both corresponding to the low-elevation collection site.

In all of the gardens, we annually collected data on height, persistence, and utilization by jackrabbits. Jackrabbit utilization was rated on a scale of 10 to 100 with 10 being no utilization, 20 slight utilization, 50 moderate utilization, 75 use of twigs to 0.20 inches (0.5 cm) diameter, and 100 the digging out of the plant crowns. Data were subjected to analysis of variance. Duncan's multiple range test was used to separate means where appropriate. Nonparametric statistical analysis was used to analyze the jackrabbit preference data (Siegel 1956).

RESULTS

Granite Peak - Initial Nursery

Plants of fourwing saltbush grown from seed collected from the surviving pistillate plants of the high elevation Mojave source were planted back at the Granite Peak nursery in 1974 (table 1). All of these plants survived and were still alive in 1982. Their growth was compared to the growth of plants of the staminate parent originally collected in Washoe County, Nev. The F_1 hybrid plants were considerably more vigorous, reaching a height of 39 inches (1 m) when planted at 39 inches (1 m) spacing. The F_1 plants flowered and produced some seed the first season. The nursery at Granite Peak did not suffer jackrabbit predation in 1974.

Churchill Canyon Nursery

In 1975, we planted both F_1 and F_2 seed plus plants of both parents at Churchill Canyon and Granite Peak (table 2). The natural plant communities found at the two sites indicate the Churchill Canyon location is much more xeric than Granite Peak.

There was no significant ($P \leq 0.05$) difference in initial establishment of transplants at Churchill Canyon (table 2). The nursery was protected by a jackrabbit-proof fence so there was no predation. Greatest first-season growth was made by the Washoe parents and plants from the gigas diploid source. Least growth was made by the Mojave parent and the hybrids. The height of the Mojave parent ranged from 8 to 20 inches (20 to 50 cm) and the Washoe parent from 20 to 32 inches (50 to 80 cm) at the end of one spring season (fig. 2). The F_1 population ranged in height from 12 to 24 inches (30 to 60 cm) and the F_2 from 8 to 24 inches (20 to 60 cm).

1971 Original seed collections of fourwing saltbush

Mojave Desert Low elevation	Mojave Desert High elevation	Washoe County Nevada

1972 Planted at Granite Peak, Nevada

Mojave Desert Low elevation	Mojave Desert High elevation	Washoe County Nevada
All plants winterkilled	Two pistillate plants survived	All plants survived

1973 Plants hybridized

1974 F_1 plants at Granite Peak

1975 Both F_1 and F_2 plants at Granite Peak
F_1 plants at Churchill Canyon

1976 F_2 plants at Granite Peak and Churchill Canyon

1977 F_2 plants at Gund Ranch

1979 F_2 plants at Ridgecrest, Mojave, and Granite Peak

Figure 1.--Sequence of plant material used in study.

Table 1.--Survival and height growth of F_1 hybrid and Washoe County, Nev., collections of fourwing saltbush in a garden located at Granite Peak, Nev.[1]

Plant material	Number planted 1974	1974		1975		1982	
		Survival	height	Survival	height	Survival	height
		%	cm	%	cm	%	cm
F_1 hybrid plants	150	100	50	100	100	100	100
Washoe County, Nevada collection (staminate parent of hybrid)	20	100	40	100	60	85	60

[1]There were no significant differences among means.

Table 2.--Survival and height of F_1, F_2, Washoe County (Nevada) and Mojave (California) collections and gigas diploid fourwing saltbush plants at Churchill Canyon and Granite Peak garden sites[1] at the end of the growing season.

	Survival and height/over time					
	1975		1976		1982	
Garden Location and Plant Material	Survival	Height	Survival	Height	Survival	Height
	%	cm	%	cm	%	cm
Churchill Canyon						
F_1 hybrid	90	50b	90a	80b	80a	100ab
F_2 hybrid	80	40b	60b	60b	40b	80b
Washoe parent	90	70ab	60b	80b	40b	100ab
Mojave parent	80	40b	10c	80b	10c	80b
Gigas diploid	90	100a	80ab	120a	60ab	120a
Granite Peak						
F_1 hybrid	90a	50	80a	100a	80a	100a
F_2 hybrid	80a	30	20b	60b	20b	60b
Washoe parent	10b	30	0b	0c	0b	0c
Mojave parent	80a	40	0b	0c	0b	0c
Gigas diploid	20b	60	0b	0c	0b	0c

[1]Churchill Canyon garden protected by jackrabbit-proof fence. Means within columns, within locations followed by the same letter are not significantly different at the 0.05 level of probability as determined by Duncan's multiple range test. No letters indicate no significant differences.

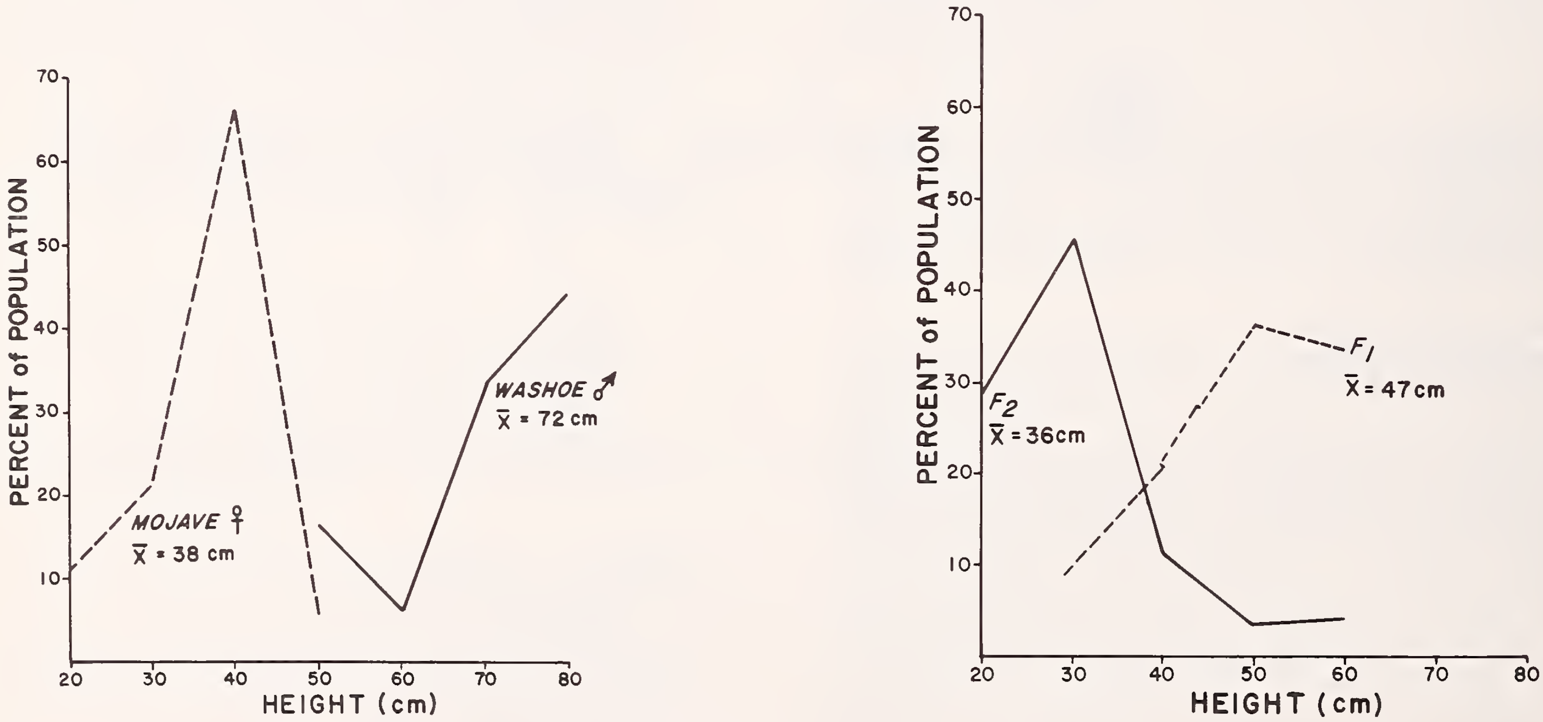

Figure 2.--Height (cm) distributions of parents (left) and F_1 and F_2 generations (right) of fourwing saltbush grown at Churchill Canyon, Nevada, in 1975 at the end of the first growing season after transplanting.

In the spring of 1976 at Churchill Canyon, only 10 percent of the fourwing saltbush plants of the Mojave source were alive; however, 80 percent of the plants of the Washoe parent were alive. (Data not shown; figures in table 2 are for the end of the growing season in 1976, a period of severe drought at the site). Fourwing saltbush plants of both the F_1 and F_2 populations survived the winter although 20 percent of F_2 plants died by the end of the growing season.

By the end of the second growing season (1976), plants from the gigas source had significantly ($P < 0.05$) more growth than plants of any other source.

In 1982, 7 years after the transplants were established at Churchill Canyon, the F_1 hybrid and gigas diploid populations had the greatest survival rates (table 2). The 39 inches (1 m) spacing used in this nursery probably greatly exceeded the site potential. A wider spacing of the plants probably could have increased survival.

Granite Peak - Second Nursery

Predation by jackrabbits at Granite Peak in 1975 severely damaged many of the fourwing saltbush plants (table 2). The increase in jackrabbit predation between 1974 and 1975 apparently was a result of: (a) an increase in the jackrabbit population, (b) a relatively dry and short growing season that limited production of forage, and (c) heavy grazing by cattle outside the nursery exclosure where the forage had been rested the previous season. Transplants of the Washoe parent and the plants of the gigas source were severely browsed the first season they were transplanted. The Mojave parents and the F_1 and F_2 hybrids were relatively resistant to jackrabbit browsing.

On the jackrabbit preference scale, the Mojave parent had an average rating of 12 and the Washoe parent 99 (fig. 3). The F_1 population was nearly as resistant as the Mojave parent. F_2 plants showed a wide range of jackrabbit browsing from 10 to 100 on the rating scale, but the bulk of the population was not preferred by jackrabbits.

The Mojave parent plants of fourwing saltbush survived the jackrabbits, but succumbed to winterkill at Granite Peak (table 2). The combination resulted in complete mortality of plants from the gigas source in the Granite Peak Nursery. In 1982, 80 percent of the F_1 plants and 20 percent of the F_2 populations were all that persisted.

Gund Ranch Nursery

Initial establishment of fourwing saltbush transplants in the Gund Ranch nursery was excellent (table 3). Again, the Washoe parent, gigas, and F_1 hybrid populations had the greatest first season growth.

During the winter of 1977-78, the fourwing plants in the nursery were subjected to severe jackrabbit browsing. This hedging, combined with winterkill, eliminated all but the hybrid populations by 1979. The plants of the hybrid populations were severely hedged by jackrabbit browsing during the next 3 years.

Mojave Nurseries

When the parent and F_2 populations were planted in nurseries in the Mojave Desert, the Mojave parent population had, numerically, greatest survival and height growth (table 4). These plants were protected from jackrabbit browsing, but the plants in the Ridgecrest nursery were browsed by other small animals.

DISCUSSION

Studies by Stutz (1978) have demonstrated that the *Atriplex* species are a rapidly evolving group with a great deal of genetic variability. Results from this present study indicate that, for the characteristics of winter hardiness and preference by jackrabbits, much variability that is apparently heritable can be found in fourwing saltbush populations. The potential for selection from hybrid populations for these characteristics is quite apparent.

Of immediate practical significance is the demonstrated lack of winter hardiness shown by most of the plants from the Mojave Desert. As previously shown by Van Epps (1975), knowledge of the seed source is a requirement when purchasing seed of fourwing saltbush for seeding on ranges where winter hardiness may be a problem.

Unfortunately, we did not record jackrabbit browsing of the fourwing saltbush plants by gender. There is evidence that different species of browsers show preference for either pistillate or staminate plants.[2]

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[2]Personal communication from Dr. E. Durant McArthur, USDA Forest Service, Shrub Sciences Laboratory, Provo, Utah.

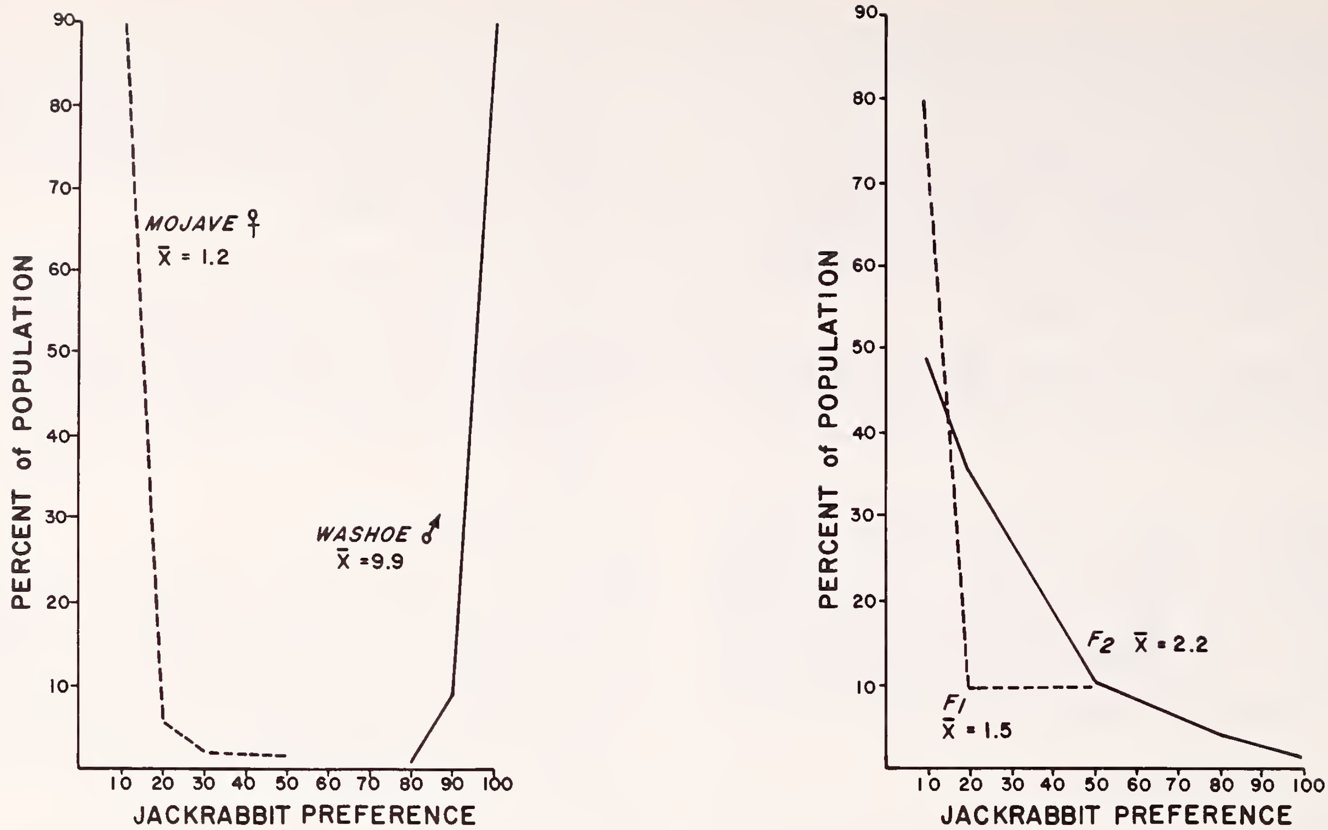

Figure 3.--Preference of jackrabbits for fourwing saltbush plants of Mojave and Washoe parents (left) and F_1 and F_2 populations (right) at Granite Peak in 1975. Rating of 10 indicates no discernible use, and 100 the digging of the plant crowns from the ground.

Table 3.--Height and survival of F_1, F_2, Washoe County (Nevada) and Mojave (California) collections and diploid fourwing saltbush plants at Gund Ranch Garden. Plants transplanted in 1977.[1]

	Height and survival over time					
	1977		1978		1982	
Plant material	Survival	Height	Survival	Height	Survival	Height
	%	cm	%	cm	%	cm
F_1 hybrid	100	60ab	80a	60	80	60
F_2 hybrid	100	50b	40b	50	20	50
Washoe parent	100	60ab	0c	0	0	0
Mojave parent	90	40b	0c	0	0	0
Gigas diploid	100	80a	10c	40	0	0

[1]Means within columns followed by the same letter are not significantly different at 0.05 level of probability as determined by Duncan's multiple range test. No letters indicate no significant differences.

Table 4.--Survival and height of Mojave and Washoe parents and F_2 populations of fourwing saltbush plants at two locations in the Mojave Desert of California. Plants transplanted in 1980[1].

Garden location and plant material	1981 Survival	1981 Height
	%	cm
Ridgecrest		
Mojave parent	87	35
Washoe parent	67	33
F_2	60	33
Mojave		
Mojave parent	89	40
Washoe parent	86	25
F_2	67	23

[1]There were no significant differences among means.

PUBLICATIONS CITED

Blackburn, W. H.; Tueller, P. T.; Eckert, R. E. Jr. Vegetation and soils of the Churchill Canyon watershed. R-45. Reno: University of Nevada Agricultural Experiment Station; 1969.

Dayton, W. A. Important western browse plants. Misc. Publ. 101. Washington, DC: U.S. Department of Agriculture; 1931. 213 p.

McArthur, E. D. Environmentally induced changes of sex expression in Atriplex canescens. Heredity. 38: 97-103; 1977.

McArthur, E. D. Stevens, R.; Blauer, A. C. Growth performance comparisons among 18 accessions of fourwing saltbush (Atriplex canescens) at two sites in central Utah. J. Range Manage. 35: 78-81; 1983.

Nord, E. C.; Stallings, J. R. Rabbits show different preferences according to saltbush (Atriplex) species and strains. In: Proceedings, symposium and workshop on wildland shrubs. U.S. Forest Service, Provo, UT: 1975; 147-148.

Siegel, S. Non-parametric statistics for the behavioral sciences. New York: McGraw-Hill; 1956: 184-194.

Smith, J. G. Fodder and forage plants, exclusive of the grasses. Bull. 2. Washington, DC: U.S. Department of Agriculture, Division of Agrostology. 1900. 86 p.

Springfield, H. W. Germination and establishment of fourwing saltbush, Res. Pap. RM-55. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1970. 48 p.

Stutz, H. C. Explosive evolution of perennial Atriplex in western America. Great Basin Naturalist Memoirs. 2: 161-168; 1978.

Stutz, H. C.; Melby, J. M.; Livingston; G. K. Evolutionary studies of Atriplex: a relic gigas diploid formation of Atriplex canescens. Am. J. Bot. 62: 236-245; 1975.

Young, J. A.; Evans, R. A. Downy brome intruder in the plant succession of big sagebrush communities in the Great Basin. J. Range Manage. 6: 410-415; 1973.

Young, J. A.; Evans, R. A., eds. Physical, biological and cultural resources of the Gund Research and Demonstration Ranch of Nevada. ARM-W-11. Oakland, CA: U.S. Department of Agriculture, Agricultural Research Service; 1980. 72 p.

Van Epps, G. A. Winter injury to fourwing saltbush. J. Range Manage. 28: 157-159; 1975.

In: Tiedemann, Arthur R.; McArthur, E. Durant; Stutz, Howard C.; Stevens, Richard; Johnson, Kendall L., compilers. Proceedings--symposium on the biology of Atriplex and related chenopods; 1983 May 2-6; Provo, UT. General Technical Report INT-172. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 309 p.

SURFACE SOIL AND SEEDBED ECOLOGY IN SALT-DESERT PLANT COMMUNITIES

Bruce A. Roundy, Raymond A. Evans, and James A. Young

ABSTRACT: The salt-desert seedbeds are harsh environments for seed germination and seedling growth. In the absence of frequent spring rains the total water potential of the surface soil decreases rapidly as soil matric and osmotic potentials decrease due to water loss and upward movement of salts. Even a moderately saline soil may have much lower water potentials than nonsaline soil due to the low osmotic potential of the soil solution. Soil surface cracks are important safe sites for germination and seedling emergence in these seedbeds.

INTRODUCTION

Salt-desert shrub vegetation, composed dominantly of chenopods (West 1983), has been estimated to occupy 37 to 42 million acres (15 to 17 million hectares) in the western United States (Branson and others 1967; Küchler 1964). Caldwell (1974) and West (1983) have characterized the environment of saline deserts as having high seasonal temperature and precipitation fluctuations resulting in a short period of time when active growth is not limited by extreme temperatures and lack of moisture.

Precipitation in the Great Basin mainly occurs in fall, winter, and spring. Storms producing effective precipitation become less frequent, but possibly more critical to seedling establishment, from March through June or July as temperatures become favorable for germination and growth (fig. 1). Chemical and physical properties of salt-desert soils may affect soil water availability to plants during this critical spring period or may have a direct effect on germination, emergence, and growth. An understanding of the characteristics of salt-desert soils is not only necessary to understand natural plant distribution, but is also necessary in determining range improvement and management practices. This paper will discuss some of the properties of salt-desert soils that affect plant distribution, growth, and establishment. It also presents water potential, salinity, and soil penetrability data for a salt-desert soil in central Nevada.

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LITERATURE

Much research has been devoted to the description and classification of salt-desert communities and soils in an effort to relate plant distribution to site characteristics (Kearney and others 1914; Shantz and Piemeisel 1924 and 1940; Flowers 1934; Billings 1945; Fauntin 1946; Gates and others 1956; Vest 1962; Mitchell and others 1966; Branson and others 1967; West and Ibrahim 1968; Goodman 1973; Miller and others 1982). Distribution and growth of salt-desert species have been related to numerous edaphic factors and interactions of the factors. Some important factors are: (1) tolerance of plants to total salt content of the soil (Billings 1945; Bolen 1964; Daubenmire 1970; Dodd and Coupland 1966; Flowers 1934; Hunt and Durrel 1966; Kearney and others 1914; Keith 1958; Ungar 1962 and 1966; Ungar and others 1969), (2) tolerance to relative amounts of specific ions in the soil solution (Flowers 1934; Heimann 1966; Naphan 1966; Tiku 1975), (3) depth of soil salinity (Billings 1945; Fautin 1946; Shantz and Zon 1924), (4) tolerance to flooding and poor soil aeration (Daubenmire 1970; Dodd and Coupland 1966; Evans 1953; Flowers 1934; Shantz and Piemeisel 1940), (5) water table depth and quality of ground water (Billings 1951; Bolen 1964; Daubenmire 1970; Fautin 1946; Flowers 1934; Harris and others 1924; Hunt and Durrel 1966; Jackson and others 1956; Robinson 1958; Shantz and Zon 1924; Shantz and Piemeisel 1924 and 1940; White 1932), and (6) soil texture as related to geology and erosion patterns (West and Ibrahim 1968). Other important considerations in relating growth and distribution of halophytes to soil conditions include: (1) total soil moisture potential and the proportionality of its components, osmotic and matric potential (Branson and others 1967; Goodin 1975; Miller and others 1982), (2) seasonal variability of such factors as salinity and moisture as related to germination and growth (Evans 1953; Jackson and others 1956; Goodin 1975), (3) ecotypic adaptation to specific soil conditions (Clark and West 1971; Goodin 1975; Goodman and Caldwell 1971; Goodman 1973; Workman and West 1967 and 1969), and (4) the synecological context in which the plant occurs relative to its ability to compete and reproduce (Billings 1952; West and Tueller 1971).

The internal drainage of the Great Basin has resulted in an accumulation of salts and fine sediments in the many closed basins created by basin and range faulting in the Miocene (Papke 1976). The predominant ions accumulated in surface soils of many valleys of the Great Basin are Na, Cl, and SO_4 with comparatively little Ca and Mg (Shantz and Piemeisel 1940; Gates and others 1956; Vest 1962; Stuart and others 1971; Ando 1958;

Roundy 1983[1]). These sodium salts are highly soluble and reduce the total soil water potential by reducing the soil solution osmotic potential linearly with decreasing water content (Roundy 1983)[1]. The high sodicity of these fine-textured soils also reduces infiltration (Hayward and Wadleigh 1949). Soil salts may also limit germination and growth by entering the seed or plant and creating nutritional imbalances or interfering with physiological processes (Bresler and others 1982). In addition to Na, high B concentrations have been reported in salt-desert soils (Robinson 1970) and may limit growth of some plants.

Surface soil salinity may vary with season, precipitation, and capillary rise from the water table (Jackson and others 1956). High winter precipitation may increase surface salinity by raising the water table so the capillary fringe is near the soil surface. Salts are deposited on the surface as water evaporates (Richards 1954). If the water table is deep or evapotranspiration breaks the capillary chain, surface salinization stops (Jackson and others 1956). Lowland Great Basin soils vary in amount and vertical concentration of salts due to differences in depth to the water table. Spring precipitation may increase soil osmotic potential by leaching salts accumulated in the surface soil or by removing them in runoff water and by diluting the soil solution. Teakle and Burvill (1938) found substantial leaching of salts in sandy and medium-textured soils of western Australia, but not in heavy-textured soils. In the Thar Desert, India, rainy season precipitation leached salts and increased subsurface soil moisture, resulting in increased plant and soil osmotic potentials (Rajpurohit and Sen 1980). Zallar and Mitchell (1970) suggested that autumn rains leached salts on dry hard-pan sites in Australia, allowing germination and establishment of salt-tolerant grasses. Soil salinity and sodicity decreased after contour furrowing in southeastern Montana presumably due to increased infiltration and leaching (Soiseth and others 1974). Spring rains could also decrease the osmotic potential of the subsurface soil solution by washing down salts that have precipitated out on the soil surface.

Salt-desert chenopods accumulate high amounts of Na, K, and Cl (Eckert and Kinsinger 1960; Rickard 1965; Chatterton and others 1970; Wiebe and Walter 1972). These salts may allow salt-desert shrubs to osmotically adjust to low soil water potentials (Caldwell 1974). They also increase the salinity and sodicity of the soil surface when leached from fallen litter and live plant parts (Roberts 1950; Fireman and Hayward 1952; Eckert and Kinsinger 1960; Rickard and

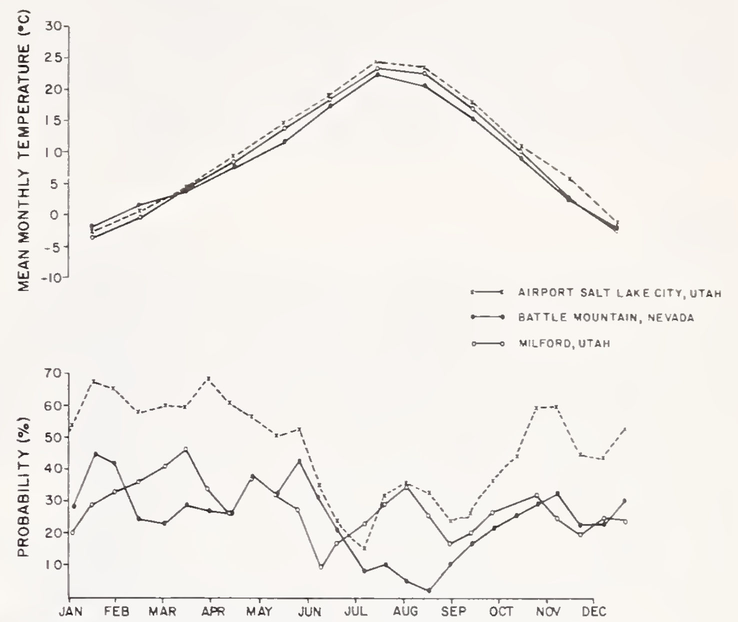

Figure 1.--Mean monthly temperatures (above, U.S. Dep. Comm. 1979, 1982) and probabilities of receiving 1 cm of precipitation in a 2-week period (below, Gifford and others 1967) for three salt-desert weather stations in the Great Basin.

others 1973; Sharma and Tongway 1973). Although the accumulation of salts under shrubs may reduce infiltration and result in ion concentrations toxic to some plants, the litter fall area is also associated with higher soil fertility than the interspaces (Rickard and others 1973; Charley and West 1975). Also, coarse-textured shrub mounds associated with windblown soil accumulations may be more readily leached and lower in salinity, sodicity, and B than interspace soils (Rollins and others 1968; Stuart and others 1971).

The fine-textured soils generally associated with the salt-desert have high water-holding capacity, but they may limit soil water availability. Low organic matter and high sodicity result in high particle dispersion (Blackburn 1975) which causes low infiltration and hydraulic conductivity. Eckert and others (1978) have described the surface soil morphology associated with shrub mounds and interspaces of aridisols in Nevada. Regular organic matter additions from shrub litter fall result in friable, well-aggregated mound soils which have high infiltration rates. In the interspaces, the lack of organic matter and repeated wetting and drying (Miller 1971) may cause silty soils to form a platey to massive vesicular crust. This decreases soil penetrability and may restrict seedling emergence. Stephens (1980) found that slightly crusted pinnacled soil surfaces or crusted polygonal units separated by cracks were important microsites for seedling emergence in vesicular crusted soils in Nevada. Duba (1976) observed halogeton (Halogeton glomeratus C. A. Mey) seedlings emerge mainly from cracks between polygonal soil surface peds. These cracks are undoubtedly safe sites (Harper 1977) for seedling emergence. They catch seeds and allow unrestricted emergence, compared to the hard crusts of the soil polygons.

[1]Roundy, Bruce A., Estimation of water potential potential components of saline Great Basin rangeland soils, unpublished draft; 1983.

Seedling establishment in deserts may occur sporadically due to one or a culmination of favorable moisture events (Noy-Meir 1973). It has been hypothesized that high seedling establishment may be the product of years of weather conditions favoring high seed set, germination, and seedling survival (Went 1955; West 1979).

METHODS

To determine the effects of high spring precipitation on salinity, water potential components, and crust penetrability, a nonsaline and a moderately saline salt-desert soil were sampled in the spring and summer of 1982 in central Nevada. The saline soil is a Gund silt-loam series identified as of the fine-silty over clayey, mixed (calcareous), mesic family of Aquic Durorthidic Torriorthents. The nonsaline soil is of the fine, montmorillonitic, mesic family of Typic Camborthids. Both soils supported a greasewood/salt rabbitbrush/basin wildrye (Sarcobatus vermiculatus (Hook.) Torr./Chrysothamnus nauseosus (Pallas) Britt. ssp. consimilis (Greene)/Elymus cinereus Scribn. and Merr.) community. The shrubs were eliminated by spraying with 3 lb/acre (3.4 kg/ha) of 2,4-D ((2,4-dichlorophenoxy) acetic acid) in the spring of 1980 and by rotobeating later in the summer. Soils were seeded to tall wheatgrass (Agropyron elongatum (Host Beauv. 'Jose') and basin wildrye (Elymus cinereus Scribn. and Merr. 'Magnar') in the fall of 1981.

Natural precipitation from November 1981 to March 1982 was average for the site at 5.5 inches (13.9 cm), but spring precipitation from April through June was 1.8 inches (4.6 cm), about 2 inches (5 cm) below average. Thus 1981-82 had a relatively wet winter and dry spring and was a good year to measure the effects of supplemental precipitation, simulated by irrigation, on soil salinity and water potential. A gradient in spring precipitation was created by irrigating the soils with a single sprinkler on four dates in May and June 1982. Water applied decreases almost linearly with the distance from the sprinkler (Hanks and others 1976). Soils were sampled at depth intervals of 0-0.4, 0.4-2.0, 2.0-4.0, 4.0-6.0, and 9.8-11.8 inches (0-1, 1-5, 5-10, 10-15, and 25-30 cm) at approximately 2-week intervals from late April through mid-August. Soils were generally sampled 2 weeks after each of the four irrigations. On each sample date, two mound and two interspace soils were sampled at distances of 8.2, 21.3, 34.5, and 52.5 feet (no irrigation) (2.5, 6.5, 10.5, and 16 m) from the sprinkler. The highest irrigation 8.2 feet (2.5 m) from the sprinkler, added a total of 4 inches (10 cm) of water to the 1.8 inches (4.6 cm) of natural rain that fell from April through June.

Total water potential of the samples was determined in psychrometer chambers. Soil osmotic potentials were estimated from measurements of volumetric water content and electrical conductivity of the saturation extract (ECe) as described in detail by Roundy (1983)[1]. Matric potential was estimated by subtracting osmotic from total water potential. Crust penetrability was measured, in relation to precipitation and irrigation, by recording the pressure necessary to push a 0.8-inch (2-cm) diameter by 1.6-inch (4-cm) long penetrometer cone with a 30-degree angle into the soil until the top of the cone was flush with the soil surface.

RESULTS

Salinity

The saline soil had an average ECe of 7.0 $dS \cdot m^{-1}$ [2/] and an average sodium absorption ratio (SAR) of 44 in the upper 11.8 inches (30 cm). The water table in the saline soil was 6.9 feet (2.1 m) deep and fluctuated less than 1 foot (0.3 m) during the year. Except for the surface 0-0.4 inch (0.1 cm) of soil, salinity generally increased with depth (fig. 2A). Excavations indicated a zone of dry soil and therefore no capillary chain between the water table and the surface soil. Changes in salinity in the surface were a function of initial salinity conditions, precipitation, and evapotranspiration.

Salinity of the surface 0-0.4 inch (0.1 cm) was lowest in early spring following winter precipitation, then increased greatly in mid-spring as the soil began drying and salts accumulated in the surface (fig. 2A). Salinity then decreased over summer possibly as a result of wind erosion.

Subsurface salinity 0.4-6 inches (1-15 cm) increased gradually from early spring through summer probably due to an upward movement of water and salts as the upper soil dried (fig. 2A). Spring irrigation decreased this upward movement of salts, probably by continued leaching.

Important implications for plants are that the seedbed surface may be very high in salinity as the soil dries in response to warming spring temperatures, but increased spring precipitation may keep the salinity of the root zone low. The salinity of mounds and interspaces was very similar in these soils. From April through August the upper 0.4-6 inch (1-15 cm) of mounds and interspaces had an average ECe of 5.0 and 5.7 $dS \cdot m^{-1}$, respectively.

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[2] $dS \cdot m^{-1}$ = decisiemen per meter = $mmho \cdot cm^{-1}$

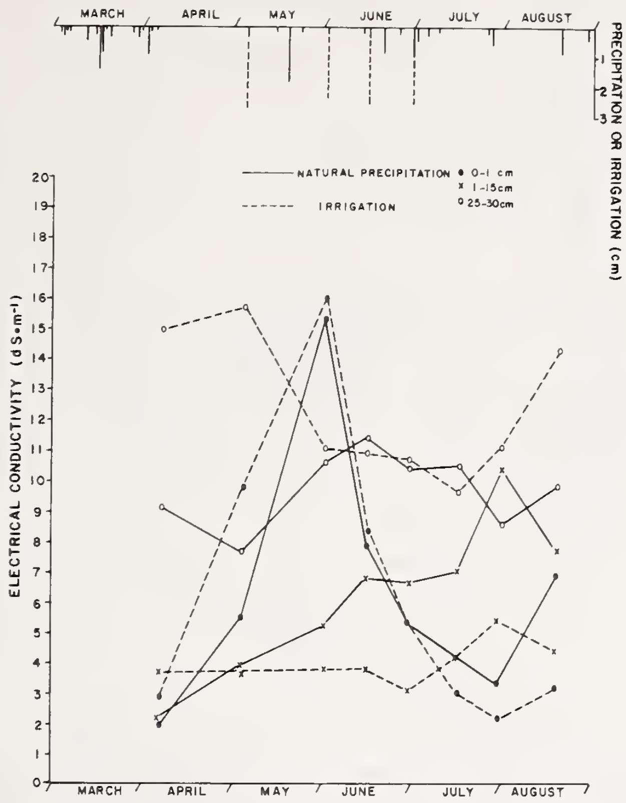

Figure 2A.--Electrical conductivity of the saturation extract for a saline soil in Grass Valley, Nevada, receiving natural precipitation and irrigation in the spring and summer of 1982.

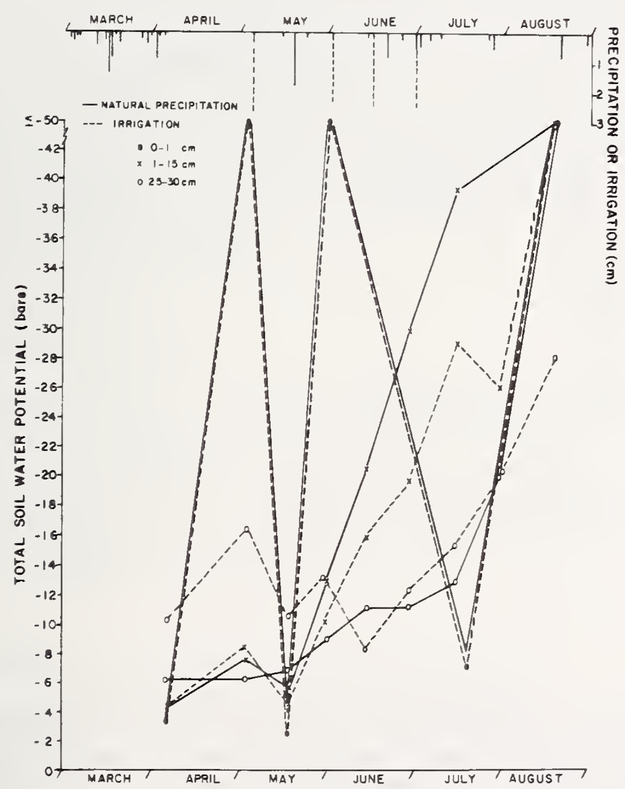

Figure 2B.--Total soil water potentials for a saline soil in Grass Valley, Nevada, receiving natural precipitation and irrigation in the spring and summer of 1982.

Figure 2C.--Osmotic soil water potentials for a saline soil in Grass Valley, Nevada, receiving natural precipitation and irrigation in the spring and summer of 1982.

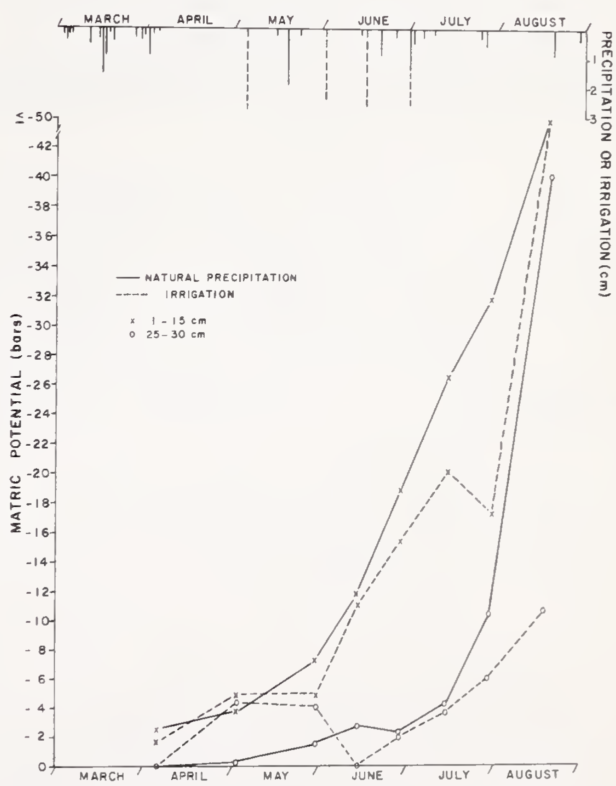

Figure 2D.--Matric soil water potentials for a saline soil in Grass Valley, Nevada, receiving natural precipitation and irrigation in the spring and summer of 1982.

Water Potential Components

Total water potential of the surface 0-0.4 inch (0-1 cm) of soil increased and decreased rapidly in response to precipitation and drying periods (fig. 2B). In the absence of frequent storms, seeds would either have to germinate very rapidly in the surface soil or be able to emerge from lower depths which have much higher and less fluctuating water potentials. Seeds germinating in cracks would be expected to avoid the high salinity and low water potential fluctuations of the surface soil.

Total soil water potential began decreasing in early June and continued to decrease sharply over the summer (fig. 2B). Moore and Caldwell (1972) and Everett and others (1977) have reported similar seasonal decreases in the soil water potential of shadscale (Atriplex confertifolia (Torr. and Frem.) Wats.) communities. Irrigated subsurface soil had higher total water potentials than nonirrigated soil. Irrigation decreased salinity by leaching and by increasing soil water content, thereby increasing soil osmotic and matric potentials (fig. 2). Total soil water potential of the saline soil receiving the highest irrigation (3 - 1 inch (2.5 cm) irrigations in June) still decreased rapidly from June through the summer (fig. 2B). Irrigation or storms are less effective in maintaining high soil water potentials in late spring and early summer than in early spring because of increased evapotranspiration associated with warming temperatures. Osmotic potential of the irrigated soil at 9.8-11.8 inches (25-30 cm) was more negative than that of the nonirrigated soil due to higher salinity. This difference in salinity was probably a result of horizontal variations in salinity concentrations. The irrigated soil maintained higher matric potentials at 9.8-11.8 inches (25-30 cm) than the nonirrigated soil after midsummer.

The nonsaline soil generally had higher total water potentials than the saline soil (fig. 3 and 4). The lower total water potential of the saline soil can be attributed to its osmotic potential where the matric potentials of the two soils were similar (fig. 3). The osmotic and matric potentials were each about 50 percent of the total water potential of the saline soil in the spring when soil water content was comparatively high. In April and May, soil osmotic potential decreased with depth as soil salinity increased. Matric potential increased with depth due to increasing soil water content (fig. 2C, 2D). As water content decreased in the summer, the matric potential decreased more rapidly than osmotic potential and thereby became the dominant component of the total soil water potential. As soil water content decreases to a point, matric potential decreases logarithmically. Osmotic potential in soils with highly soluble salts decreases linearly with decreasing water content. This linear decrease in soil osmotic potential, and the gradual increase in soil salinity resulted in increasingly more negative total water potentials for the saline soil compared to the nonsaline soil through the summer.

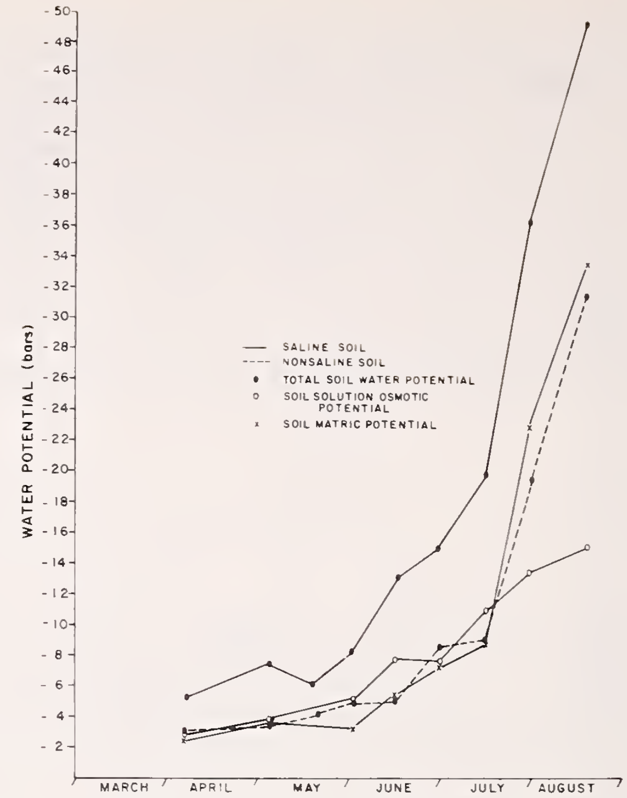

Figure 3.--Total, osmotic, and matric soil water potentials for a saline soil, and total soil water potential of a nonsaline soil for the 4-6 inches (10-15 cm) depth interval in the spring and summer of 1982 in Grass Valley, Nevada.

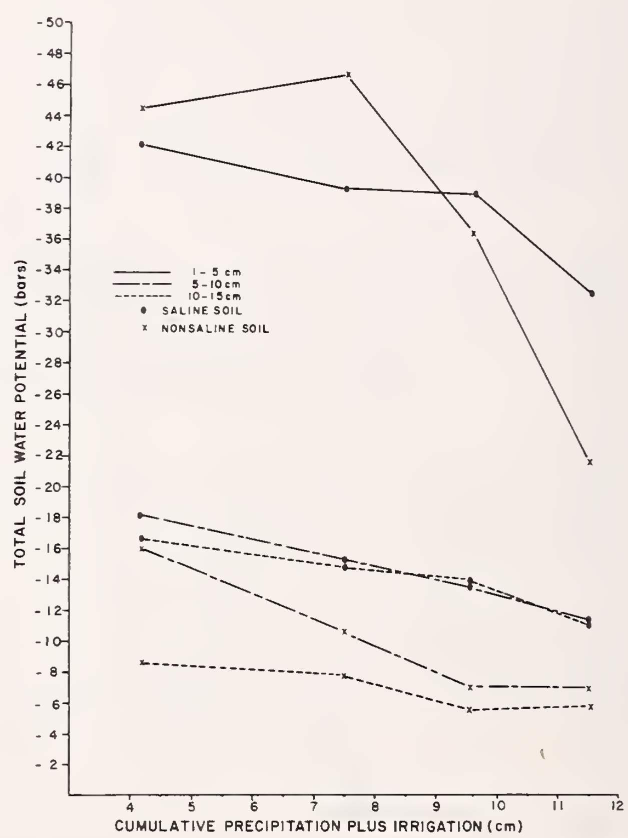

Figure 4.--Average total soil water potential of a saline and a nonsaline soil between May 18 and July 8, 1982 as a function of cumulative precipitation plus irrigation for the same time period in Grass Valley, Nevada.

Plants in these environments which can adjust osmotically may avoid the soil osmotic component of total soil water potential. These plants may grow similarly in saline and nonsaline soils, if they are tolerant to low cell osmotic potentials and accumulated ions. Differences in the ability of salt-desert plants to accumulate ions and osmotically adjust may be related to adaptability to soils of different salinities and osmotic and matric proportions of the total water potential.

The effects of increasing irrigation amounts on total soil water potential of the saline and nonsaline soils from 2 weeks after the first irrigation to 2 weeks after the last irrigation are shown in figure 4. Irrigation amount had a greater effect on increasing the total potential of the 0.4-2 inch (1-5 cm) interval of the saline soil and the 2-4 inch (5-10 cm) interval of the nonsaline soil than it had on other depth intervals. A smaller effect of irrigation amount on the water potential of deeper intervals of the saline soil may have been a result of low infiltration due to the high SAR. Since soil samples were taken 2 weeks after irrigations, the differences in water potential due to irrigation amount were probably minimized because of evapotranspirational water losses. These data underscore the importance of frequent spring rains in maintaining favorable water potentials of saline surface soils, especially for seeds that require warm temperatures for germination.

For the saline soil, mounds had total water potentials an average of 3 bars lower than interspace soils in the upper 0.4-6 inches (1-15 cm) between April and the end of June. Since salinity of the mounds and interspace soils was similar, the differences in total potential would be due to differences in matric potential rather than osmotic potential. A graph of the moisture release curves, as determined by a pressure plate, showed that at given water contents, mound soil had more negative potentials than interspace soil, even though the particle size distribution of both soils was similar.

Soil Penetrability

Shrub mound soils were much more penetrable than interspace crusts (fig. 5) and would offer little mechanical resistance to emerging seedlings. The penetrability of interspace soils increased with the amount of irrigation, but decreased again rapidly as the soil dried.

DISCUSSION

Total water potentials are at a maximum in early spring following the winter period of high precipitation and low evapotranspiration. During this time, matric potentials are high due to high soil water content. Soil solution osmotic potentials are maximum due to leaching of salts and high soil water content. With increasing temperatures and the absence of frequent spring rains, salinity may increase and water potential decrease greatly in the surface soil as it dries.

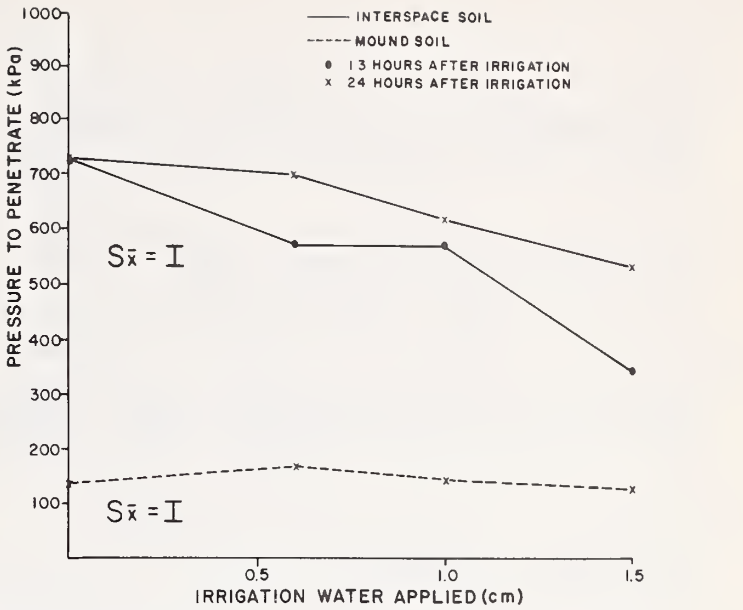

Figure 5.--Pressure required to penetrate mound and interspace salt-desert soils in Grass Valley, Nev., in relation to amount of irrigation and time after irrigation.

The vesicular crust of interspaces may soften after spring rains, but rapidly hardens as the soil dries. Cracks separating the polygons of vesicular crusts are important safe sites for seed germination and emergence. They catch the seeds which then are able to emerge unrestricted from lower soil depths where the soil water potential is much higher and fluctuates less than in the surface soil. Natural seedling emergence of halogeton, wedgescale (Atriplex truncata (Torr.) Gray) and wildrye was observed only in crevices and cracks in the salt-desert soil in this study.

High spring precipitation favors seedling establishment on saline soils by maintaining higher total soil water potentials. As the soil surface dries in late spring and early summer, salinity of the seedbed increases. Salt-bearing water from lower depths rises in response to the more negative hydraulic potential of the drier surface soil. Frequent spring precipitation slows the accumulation of salts in the surface 0.4-6 inches (1-15 cm) of soil by continued leaching and results in higher soil solution osmotic potentials. In the absence of frequent rains, seedbed osmotic and matric potentials decrease rapidly in the spring and early summer. During years of minimal spring precipitation, seedling establishment on salt-desert soils may be dependent on rapid and early root growth and the ability to osmotically adjust to maintain root growth in the wetter, but increasingly saline, subsurface soil.

Although mound soils may be higher in fertility, aggregate stability, and penetrability, they may have the same salinity and osmotic potentials, but lower matric potentials, for a given water content than interspace soils. The results of this study underscore the importance of cracks between the soil polygons as safe sites. High spring precipitation is critical to seedling establishment in salt-desert soils.

PUBLICATIONS CITED

Ando, K. Field survival and rooting ability of Elaegnus angustifolia and Tamarix pentandra. Reno: University of Nevada; 1980. 119 p. M.S. Thesis.

Billings, W. D. The plant associations of the Carson Desert region, western Nevada. Butler Univ. Bot. Studies 7: 89-123; 1945.

Billings, W. D. Vegetation zonation in the Great Basin of western North America. In: Les Bases Ecologique de la Regeneration des Zones Arides. Paris: U.I.S.B.; 1951: 101-122.

Billings, W. D. The environmental complex in relation to plant growth and distribution. Q. Rev. Biol. 27: 251-265; 1952.

Blackburn, W. H. Factors influencing infiltration and sediment production of semiarid rangelands in Nevada. Water Resources Res. 11: 929-937; 1975.

Bolen, E. G. Plant ecology of spring-fed salt marshes in western Utah. Ecol. Monogr. 34: 143-166; 1964.

Branson, F. A.; Miller, R. F.; McQueen, I. S. Geographic distribution and factors affecting the distribution of salt desert shrubs in the United States. J. Range Manage. 20: 287-296; 1967.

Bresler, E.; McNeal, B. L.; Carter, D. L. Saline and sodic soils. New York: Springer-Verlag; 1982. 236 p.

Caldwell, M. M. Physiology of desert halophytes In: Reimold, R. J.; Queen, W. H.; eds. Ecology of halophytes. New York: Academic Press; 1974: 355-379.

Charley, J. L.; West, N. E. Plant-induced soil chemical patterns in some shrub-dominated semi-desert ecosystems of Utah. J. Ecol. 63: 945-964; 1975.

Chatterton, N. J.; McKell, C. M.; Bingham, F. T.; Clawson, W. J. Absorption of Na, Cl, and B by desert saltbush in relation to composition by nutrient solution culture. Agron. J. 62: 351-352; 1970.

Clark, L. D.; West, N. E. Further studies of Eurotia lanata germination in relation to salinity. Southwest Nat. 15: 371-375; 1971.

Daubenmire, R. E. Steppe vegetation of Washington. Pullman, WA: Tech. Bull. 62. Washington Agriculture Experiment Station; 1970: 131 p.

Dodd, J. D.; Coupland, R. T. Osmotic pressures of native plants saline soil in Saskatchewan. Can. J. Plant Sci. 46: 479-485; 1966.

Duba, D. R. Plant demographic studies of a desert annuals community in northern Utah dominated by non-native species. Logan: Utah State University; 1976. 189 p. M. S. Thesis.

Eckert, R. E., Jr.; Kinsinger, F. E. Effects of Halogeton glomeratus leachate on chemical and physical characteristics of soils. Ecology. 41: 785-790; 1960.

Eckert, R. E., Jr.; Wood, M.K.; Blackburn, W. H.; Peterson, F. F.; Stephens, J. L.; Meurisse, M. S. Effects of surface-soil morphology on improvement and management of some arid and semiarid rangelands. In: Hyder, D. N., ed. Proceedings, first international rangeland congress; 1978 August 14-18; Denver, CO: Society for Range Manage. Denver, Co.: 1978; 299-302.

Evans, L. T. The ecology of the halophytic vegetation at Lake Ellesmere, New Zealand. J. Ecol. 41: 106-122; 1953.

Everett, R. L.; Meeuwig, R. O.; Tueller, P. T.; Evans, R. A. Water potential in sagebrush and shadscale communities. Northwest Sci. 51: 271-281; 1977.

Fautin, R. W. Biotic communities of the northern desert shrub brome in western Utah. Ecol. Monogr. 16: 251-310; 1946.

Fireman, M.; Hayward, H. E. Indicator significance of some shrubs in the Escalante Desert, Utah. Bot. Gaz. 114: 143-155; 1952.

Flowers, S. Vegetation of the Great Salt Lake region. Bot. Gaz. 95: 353-418; 1934.

Gates, D. H.; Stoddart, L. A.; Cook, L. W. Soil as a factor influencing plant distribution on salt deserts of Utah. Ecol. Monogr. 26: 155-175; 1956.

Gifford, R. O.; Ashcroft, G. L.; Magnuson, M. D. Probability of selected precipitation amounts in the western region of the United States. Bull. T-8. U.S. Dept. Agric., U.S. Dept. Comm. and Agric. Exp. Stn., Univ. of Nevada, Reno.

Goodin, J. R. Salinity relations in shrubs. In: Stutz, H. C., ed. Proceedings symposium and workshop on wildland shrubs, 1975 November; Provo, UT. 1975: 1-31.

Goodman, P. J. Physiological and ecotypic adaptations of plants to salt desert conditions in Utah. J. Ecol. 61: 473-494; 1973.

Goodman, P. J.; Caldwell, M. M. Shrub ecotypes in a salt desert. Nature. 571-572; 1971.

Hanks, R. J.; Keller, J.; Rasmussen, V. P.; Wilson, G. D. Line source sprinkler for continuous variable irrigation - crop production studies. Soil Sci. Soc. Am. J. 40: 426-429; 1976.

Harper, J. L. Population biology of plants. New York: Academic Press; 1977. 892 p.

Harris, J. A.; Gortner, R. A.; Hoffman, W. F.; Lawrence, J. V.; Vallentine, A. T. The osmotic concentration, specific electrical conductivity and chloride content of the tissue fluids of indicator plants of Tooele Valley, Utah. J. Agric. Res. 27: 893-924; 1924.

Hayward, H. E.; Wadleigh, C. H. Plant growth on saline and alkali soils. In: Norman, A. G., ed. Advances in agronomy. Vol. I. New York: Academic Press; 1949: 1-38.

Heimann, H. Plant growth under saline conditions and the balance of ionic environment. In: Boyko, H., ed. Salinity and aridity - new approaches to old problems. The Hague: Junk; 1966: 201-213.

Hunt, C. B.; Durrel, L. W. Plant ecology of Death Valley, California. Geological Survey; 1966. Prof. Paper 509. U.S. Department of the Interior, Washington, DC.

Jackson, E. A.; Blackburn, G.; Clarke, A. R. D. Seasonal changes in soil salinity at Tintinara, South Australia. Aust. J. Agric. Res. 7: 20-44; 1956.

Kearney, T. J.; Briggs, L. J.; Shantz, H. L.; Lane, J. W.; Piemeisel, R. L. Indicator significance of vegetation in Tooele Valley, Utah. J. Agric. Res. 1: 365-417; 1914.

Keith, L. B. Some effects of increasing soil salinity on plant communities. Can. J. Bot. 36: 79-89; 1958.

Küchler, A. W. Potential natural vegetation of the conterminous United States. Spec. Publ. 36. American Geographical Society; 1964. 155 p.

Miller, D. E. Formation of vesicular structure in soil. Soil Sci. Soc. Am. J. 35: 635-637; 1971.

Miller, R. F.; Branson, F. A.; McQueen, I. S.; Snyder, C. T. Water relations in soils as related to plant communities in Ruby Valley, Nevada. J. Range Manage. 35: 462-468; 1982.

Mitchell, J. E.; West, N. E.; Miller, R. W. Soil physical properties in relation to plant community patterns in the shadscale zone of northwestern Utah. Ecology. 47: 627-630; 1966.

Moore, R. T.; Caldwell, M. M. The field use of thermocouple psychrometers in desert soils. In: Brown, R. W. and VanHaveren, B. P. eds. Psychrometry in water relations research. Utah Agricultural Experiment Station, Logan, UT. 1972. 165-169.

Naphan, E. A. Soils of the salt desert shrub area and their productive capabilities. In: Proceedings, salt desert shrub symposium; 1966 August 1-4, Cedar City, UT. Bureau of Land Management. 1966: 44-68.

Noy-Meir, J. Desert ecosystems: environment and producers. Annu. Rev. Ecol. and Syst. 4: 25-51; 1973.

Rajpurohit, K. S.; Sen, D. N. Osmotic potentials of plants and soils of Pachpadra salt basin in Thar desert. In: Proceedings, international symposium on arid zone research and development. Jodhpur, India: Central Arid Zone Research Institute; 1980: 191-198.

Papke, K. G. Evaporites and brines in Nevada playas. Bull. 87. Reno, NV: Nevada Bureau of Mines and Geology; 1976. 35 p.

Richards, L. A., ed. Diagnosis and improvement of saline and alkali soils. Agric. Hand. 60. Washington, DC: U.S. Department of Agriculture; 1965. 160 p.

Rickard, W. H. Sodium and potassium accumulation by greasewood and hopsage leaves. Bot. Gaz. 126: 116-119; 1965.

Richard, W. H.; Cline, J. F.; Gilbert, R. O. Soil beneath shrub halophytes and its influence upon the growth of cheatgrass. Northwest Sci. 47: 213-217; 1973.

Roberts, R. C. Chemical effects of salt-tolerant shrubs on soils. In: Proceedings, fourth international congress of soil scientists; 1950: 404-406.

Robinson, T. W. Phreatophytes. Water Sup. Pap. 1423. Washington, DC: U.S. Department of the Interior, Geological Survey; 1958.

Robinson, T. W. Evapotranspiration by woody phreatophytes in the Humboldt River Valley near Winnemucca, Nevada. Prof. Pap. 491-D. Washington, DC; U.S. Department of the Interior, Geological Survey; 1970.

Rollins, M. B.; Dylla, A. S.; Eckert, R. E., Jr. Soil problems in reseeding a greasewood-rabbitbrush range site. J. Soil and Water Conserv. 23: 138-140; 1968.

Shantz, H. L.; Piemeisel, R. L. Indicator significance of the natural vegetation of the southwestern desert region. J. Agric. Res. 28: 721-801; 1924.

Shantz, H. L.; Piemeisel, R. L. Types of vegetation in Escalante Valley, Utah, as indicators of soil conditions. U.S. Department of Agriculture; Tech. Bull. 713; 1940. 46 p.

Shantz, H. L.; Zon, R. Atlas of American agriculture. Part I (E): The natural vegetation of the United States. Washington, DC: U.S. Department of Agriculture; 1924. 29 p.

Sharma, M. L.; Tongway, D. J. Plant induced soil salinity patterns in two saltbrush (Atriplex spp.) communities. J. Range Manage. 26: 121-125; 1973.

Soiseth, R. J.; Wight, J. R.; Aase, J. K. Improvement of panspot (Solonetzic) range sites by contour furrowing. J. Range Manage. 27: 107-110; 1974.

Stephens, J. L. Seedling emergence on vesicular crusted surfaces as affected by artificial and natural cattle tramping. Reno: University of Nevada; 1980. 116 p. M.S. Thesis.

Stuart, D. M.; Schuman, G. E.; Dylla, A. S. Chemical characteristics of the coppice dune soils in Paradise Valley, Nevada. Soil Sci. Soc. Am. Proc. 35: 607-611; 1971.

Teakle, L. J. H.; Burvill, G. H. Movement of soluble salts in soils under light rainfall conditions. J. Dep. Agric. West. Aust. 15: 218-245; 1938.

Tiku, B. L. Ecophysiological aspects of halophyte zonation in saline sloughs. Plant and Soil. 43: 355-369; 1975.

Ungar, I. A. Vegetation-soil relationships on saline soil in northern Kansas. Am. Midland Nat. 78: 98-120; 1962.

Ungar, I. A. Salt tolerance of plants growing in saline areas of Kansas and Oklahoma. Ecology. 47: 154-155; 1966.

Ungar, I. A.; Hogan, W.; McClelland, M. Plant communities of saline soils at Lincoln, Nebraska. Am. Midland Nat. 82: 564-577; 1969.

U.S. Department of Commerce, National Oceanic and Atmospheric Administration. Climatological data--Utah. Asheville, NC: U.S. Department of Commerce, NOAA National Climatic Center; 1979.

U.S. Department of Commerce, National Oceanic and Atmospheric Administration. Monthly normals of temperature, precipitation, and heating and cooling degree days 1951-80, Nevada. Asheville, NC: U.S. Department of Commerce, NOAA National Climatic Center; 1982.

Vest, E. D. Biotic communities in the Great Salt Lake Desert. Ecol. and Epizool. Ser. No. 73. Salt Lake City, UT: University of Utah, Institute of Environmental Biological Research; 1962.

Went, R. W. The ecology of desert plants. Sci. Am. 192: 68-75; 1955.

West, N. E. Survival patterns of major perennials in salt desert shrub communities of southwestern Utah. J. Range Manage. 32: 442-445; 1979.

West, N. E. Intermountain salt desert shrubland. In: West, N. E. ed. Temperate deserts and semi-deserts. Ecosystems of the world. Vol. 5. Amsterdam: Elsevier Scientific Publishing Co.; 1983: 375-397.

West, N. E.; Ibrahim, K. I. Soil-vegetation relationships in the shadscale zone in south-eastern Utah. Ecology. 49: 445-456; 1968.

West, N. E.; Tueller, P. T. Special approaches to studies of competition and succession in shrub communities. In: Wildland shrubs - their biology and utilization. Gen. Tech. Rep. INT-1. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1971: 165-176.

White, W. N. A method of estimating ground-water supplies based on discharge by plants and evaporation from soil. Water Sup. Pap. Washington, DC: U.S. Department of the Interior, Geological Survey; 1932: 1-105.

Wiebe, H. H.; Walter, H. Mineral ion composition of halophytic species from northern Utah. Am. Midland Nat. 87: 241-245; 1972.

Workman, J. D.; West, N. E. Germination of Eurotia lanata in relation to temperature and salinity. Ecology. 48: 659-661; 1967.

Workman, J. D.; West, N. E. Ecotypic variation in Eurotia lanata populations in Utah. Bot. Gaz. 130: 26-35; 1969.

Zaller, S.; Mitchell, A. Pasture species for non-irrigation salt-affected land. In: Proceedings, 11th international grass congress. 1970: 138-142.

In: Tiedemann, Arthur R.; McArthur, E. Durant; Stutz, Howard C.; Stevens, Richard; Johnson, Kendall L., compilers. Proceedings--symposium on the biology of Atriplex and related chenopods; 1983 May 2-6; Provo, UT. General Technical Report INT-172. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 309 p.

VESICULAR-ARBUSCULAR MYCORRHIZAE ASSOCIATIONS IN ATRIPLEX CANESCENS (PURSH) NUTT. AND CERATOIDES LANATA (PURSH) J.T. HOWELL

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ABSTRACT: Generally, Atriplex canescens (Pursh) Nutt. was found to form vesicular-arbuscular mycorrhizal associations under field conditions. Several pathogenic fungi, Polymyxa graminis and Olpidium spp., commonly mistaken for mycorrhizal fungi, also were found to be associated with A. canescens roots. Spore numbers of vesicular-arbuscular mycorrhizal fungi in soil surrounding roots of A. canescens growing in natural and disturbed areas ranged from 230 to 2,090 per 100 g soil. In a greenhouse study, no or sparse infection of A. canescens and Ceratoides lanata (Pursh) J.T. Howell by five different vesicular-arbuscular mycorrhizal fungi was found. Also, no effect on growth of A. canescens or C. lanata infected with vesicular-arbuscular mycorrhizal fungi was observed.

INTRODUCTION

Vesicular-arbuscular mycorrhiza (VAM) is one of the most widespread symbioses between microorganisms and higher plants. This association of fungi and plant has been demonstrated to have significant impacts on the plant. VA mycorrhizal plants have been repeatedly shown to have increased biomass over nonmycorrhizal plants (Gerdemann 1968; Mossé 1973). Many scientists have attributed this growth response to increased uptake of phosphorus by infected plants when compared to controls (Bowen and others 1975; Tinker 1975; Rhodes and Gerdemann 1978). Enhanced uptake of other nutrients (e.g., zinc) can occur as well (Rhodes and Gerdemann 1978; Mosse 1981). Infection can influence favorable plant water relations by reducing plant resistance to water transport (Safir and others 1972; Hardie and Leyton 1981; Allen 1982), and may thus improve plant drought tolerance (Allen and others 1981). Infection can also effect changes in phytohormone levels (Allen and others 1980) and photosynthetic rates (Allen and others 1981).

The Chenopodiaceae is one of the few plant families that contains both mycorrhizal and nonmycorrhizal species. There is some controversy concerning the mycorrhizal status of chenopod species (Hirrell and others 1978; Malloch and others 1980). However, current evidence suggests that fourwing saltbush (Atriplex canescens [Pursh] Nutt.) and winterfat (Ceratoides lanata [L.] C. A., Mey) do form VA mycorrhizal associations (Miller 1979; Reeves and others 1979; Williams and Aldon 1976). An exception to these findings is a report of the absence of mycorrhizal infection of A. canescens growing near Las Cruces, N. Mex., by Staffeldt and Vogt (1974).

Only limited work has been conducted on the influence of VA mycorrhizae on survival and growth of A. canescens and there is no reported work on C. lanata. Under greenhouse conditions, Williams and others (1974) demonstrated an increase in growth of A. canescens infected with Glomus mosseae (Nic. and Gerd.) Gerd. and Trappe while Lindsey and others (1977) found no effect on survival or growth of A. canescens inoculated with G. fasciculatum (Thaxter sensu Gerd.) Gerd. and Trappe. In the only published report of the influence of VA mycorrhizae on A. canescens in field conditions, Aldon (1975) observed increased survival and growth of plants infected with G. mosseae over noninfected plants grown on a coal spoil site in northwestern New Mexico.

The objectives of this study were to: (1) evaluate the mycorrhizal status of A. canescens and VAM fungal spore populations in soil surrounding A. canescens roots on plants growing in natural and disturbed areas and (2) determine the response of A. canescens and C. lanata to five different VAM fungi under controlled conditions.

MATERIALS AND METHODS

The study area for evaluating the mycorrhizal status of A. canescens was located at the McKinley Mine in northwestern New Mexico approximately 3 miles (4.8 km) east of Windowrock, Ariz. Soil and root samples were collected beneath and from four different plants growing on a disturbed site (water harvesting study area on reclaimed coal spoil) and four plants on a

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nondisturbed alluvial site. Two collections of soil and roots were made during the spring, summer, fall, and winter to determine seasonal variations of VAM fungal spore density and percentage of the root system infected with VAM fungi. Approximately 12.9 ounces (400 g) soil was collected from the top 8 inches (20 cm) of soil beneath each plant using a 0.8-inch (2-cm) soil probe. After thoroughly mixing, spores were extracted from a 3.2-ounce (100-g) portion of each soil sample by the wet-sieving and decanting method of Gerdemann and Nicholson (1963). Spore number was determined microscopically using nematode counting dishes.

Approximately 8 inches (20 cm) of fine roots (diameter 0.8-inch (2-mm)) were collected from each plant and placed in FAA solution for transport and storage. In order to determine percentage of the roots system infected with VAM fungi, roots were cleared and stained using the technique of Phillips and Hayman (1970). The percentage of root infection was estimated by the Giovannetti and Mosse (1980) gridline intersect method. A total of 50 gridline intersects were observed per sample.

A study was conducted in the greenhouse to determine the infectivity and host specificity of five VAM fungi on *A. canescens* and *C. lanata*. Seeds of *A. canescens* and *C. lanata* were germinated on moist filter paper in petri dishes and transplanted into 6-inch (15-cm) plastic pots containing a low phosphorus soil. Each pot underwent one of six treatments. Treatments consisted of a soil with no VAM fungal spores added, or 100 spores of one of the following VAM fungal species: *Gigaspora margarita* Becker and Hall; *Glomus fasciculatum*, *G. macrocarpum* Tul. and Tul.; *G. microcarpum* Tul. and Tul.; or *G. mosseae*. There were four replications per treatment. After a 6-month growth period, plants were harvested and the following parameters were measured: plant height, shoot dry weight, and percentage of root systems infected with VAM fungi.

RESULTS AND DISCUSSION

Atriplex canescens from disturbed and nondisturbed plant communities throughout New Mexico were found to form mycorrhizal associations. At the McKinley Mine study area, VAM fungal infection of the roots of *A. canescens* plants growing on a disturbed reclaimed coal spoil site and nondisturbed sites ranged from 0 to 65 percent and 8 to 40 percent, respectively, over an 11-month period in 1980-81 (table 1). In another study, of the 47 plants collected from nondisturbed plant communities in central and southern New Mexico, 68 percent were VA mycorrhizal (table 2). These findings are in general agreement with those of Miller (1979) and Williams and Aldon (1976), except Miller (1979) found no VAM association with *A. canescens* plants growing on disturbed sites.

The mycorrhizal roots of plants collected from disturbed and nondisturbed plant communities contained the typical VAM fungal hyphae and vesicles, but no arbuscules were observed. However, the presence of arbuscules in VA mycorrhizae of *A. canescens* has been reported by Miller (1979) and Williams and Aldon (1976). The absence of arbuscules may be a signal that the degree of association between *A. canescens* and VAM fungi is somewhat different than that normally observed. Hirrell and others (1978) suggest that this results in a nonfunctional mycorrhizae; however, it is uncertain what constitutes a nonfunctional association. Ojala and others (1983) have demonstrated that functionality of a VAM association is very much influenced by soil extractable phosphorus, where a functional association is defined as increasing the dry weight of mycorrhizal plants as compared to controls.

In addition to VAM fungal infection, the roots of *A. canescens* plants collected from central and southern New Mexico were found to be infected with either of two pathogenic fungi, *Polymyxa graminis* Ledingham and *Olpidium* spp. (Braun) Rabenh (table 2). These fungi are common root inhabitants and are sometimes mistaken for VAM fungi. The effect of these fungi on *A. canescens* or on VAM fungi was not determined.

Spore density of VAM fungi in soil beneath plants growing on the disturbed and nondisturbed sites at the McKinley Mine was estimated for the spring, summer, fall, and winter seasons. Spore numbers of VAM fungi were generally higher in the nondisturbed soils than the disturbed soils (table 3). Spore numbers on the disturbed site ranged from a low of 230 per 100 g soil in the spring to a high of 1,300 per 100 g soil in the fall. On the nondisturbed site, spore numbers ranged from a low of 690 per 100 g soil in the fall to a high of 2,090 per 100 g soil in the spring. The spore densities found in these two habitats are considerably higher than the 1 to 10 VAM fungal spores per 100 g soil in native shrub fields in Oregon and 1 to 5 per 100 g soil in shrub areas of the Sonoran Desert of Baja Calif. reported by Rose (1980 and 1981) and the 0 to 89 per 100 g soil in desert soils in Pakistan reported by Khan (1974).

In the greenhouse study to investigate the host specificity and effectivity of five VAM fungi on *A. canescens* and *C. lanata* in a low phosphorus soil, little or no infection of the roots occurred during a 6-month growth period. *A. canescens* roots were infected at a very low level by only *G. fasciculatum* and *G. margarita*; neither fungus was found to stimulate growth (table 4). Only *G. microcarpum* infected the roots of *C. lanata*; however, no effect on growth was detected (table 5). The sparse infection along with the absence of arbuscules in the roots and lack of growth response in these two chenopod species infected with VAM fungi,

Table 1.--Mean percentage of mycorrhizal infection of _Atriplex_ _canescens_ at the McKinley Mine in northwestern New Mexico.

Plant community	1980						1981	
	April	May	July	August	September	October	January	February
Disturbed site (Reclaimed coal spoil)	39.8	0	49.0	42.3	28.5	44.5	36.0	60.5
Nondisturbed site (Alluvial)	27.0	8.0	40.3	20.8	18.8	27.0	36.0	26.5

Root samples were collected from four different plants on each site at each sampling period.

Table 2.--Percentage of _Atriplex_ _canescens_ plants infected with pathogenic fungi; _Polymyxa_ _graminis_ and _Olpidium_ spp. in nondisturbed and disturbed sites in central and southern New Mexico.

Site status	Number of plants examined	Percentage of plants infected with		
		Olpidium spp.	_Polymyxa_	Both fungi
Disturbed	20	50	15	10
Undisturbed	8	75	12	0
Undisturbed	9	6	3	--

Plants grown in a nursery environment in an alluvial field soil from Rio Grande flood plain south of Albuquerque, N. Mex. 2N KCl soluble soil analysis was: NH^+, 4.9 g/g; NO_3^-, 57 g/g; Na, 20.5 g/g; Ca, 20.5 g/g; Mg, 11.0 g/g; Mn, 3.3 g/g; P, 5.0 g/g; Zn, 2 g/g; water soluble K was 20.5 g/g and total N was 0.065 percent.

Sandy, alluvial soil on native site 32.2 miles (20 km) south of Las Cruces, N. Mex.

Site near old CCC camp 48.3 miles (30 km) northwest of Albuquerque, N. Mex. (See Williams and Aldon 1976 for description of site.)

Table 3.--Mean spore count of mycorrhizal fungi per 100 gram of soil in the rhizosphere soil of _Atriplex_ _canescens_ at McKinley Mine in northwestern N. Mexico.

Plant community	1980			1981
	Spring	Summer	Fall	Winter
Disturbed site (Reclaimed coal spoil)	230	330	1,300	320
Nondisturbed site (Alluvial)	2,090	1,310	690	1,030

Soil samples were collected from beneath four different plants at two different times during the spring, summer, fall, and winter months.

Table 4.--Response of fourwing saltbush, Atriplex canescens, to five vesicular-arbuscular mycorrhizal fungi.

Inoculum applied to plants	Dry weight of shrubs	Height of plants	Percent of roots infected
	Grams	cm	
None - (control)	0.56	5.7	0
Glomus fasciculatum	.50	3.7	1
Glomus macrocarpum	.64	5.2	0
Glomus microcarpum	.66	5.1	0
Glomus mosseae	.62	5.8	0
Gigaspora margarita	.72	7.1	1

No significant differences between treatments.

Table 5.--Response of winterfat, Ceratoides lanata, to five vesicular-arbuscular mycorrhizal fungi.

Inoculum applied to plants	Dry weight of shrubs	Height of plants	Percent of roots infected
	Grams	cm	
None - (control)	0.27	7.2	0
Glomus fasciculatum	.30	7.1	0
Glomus macrocarpum	.31	10.4	0
Glomus microcarpum	.39	6.4	1.3
Glomus mosseae	.34	8.3	0
Gigaspora margarita	.31	6.8	0

No significant differences between treatments.

indicates that a low effectivity mycorrhizal association may have been formed.

Evidence presented in this paper and others (Miller 1979; Williams and Aldon 1976; Reeves and others 1979) suggests that A. canescens and C. lanata grown in natural plant communities are generally VA mycorrhizal. However, under controlled conditions where plants are grown in soil infested with individual species of VAM fungi, mycorrhizal functionality is not apparent. Although we have no explanation for these findings, several factors may be involved: (1) edaphic factors, such as phosphorus levels, may have a pronounced influence on the mycorrhizal dependency of A. canescens (Ojala, and others 1983); (2) plants may require a degree of physiological maturation, not possible in our greenhouse studies, before infection will occur; or (3) plants in natural habitats form mycorrhizae when growing in close proximity to mycorrhizal plants (Hirrell and others 1978).

PUBLICATIONS CITED

Allen, M. F. Influence of vesicular-arbuscular mycorrhizae on water movement through Bouteloua gracilis (H.B.K.) Lag ex Steud. New Phytologist. 91: 191-196; 1982.

Allen, M. F.; Moore, T. S., Jr.; Christensen, M. Phytohormone changes in Bouteloua gracilis infected by vesicular-arbuscular mycorrhizae. I. Cytokinin increases in the host plant. Can. J. Bot. 58: 371-374; 1980.

Allen, M. F.; Smith, W. K.; Moore, T. S., Jr.; Christensen, M. Comparative water relations and photosynthesis of mycorrhizal and non-mycorrhizal Bouteloua gracilis (H.B.K.) Lag ex Steud. New Phytologist. 88: 683-693; 1981.

Aldon, E. F. Endomycorrhizae enhance survival and growth of fourwing saltbush on coal mine spoils. Res. Note RM-294. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1975. 2 p.

Bowen, G. D.; Bevege, D. I.; Mosse, B. Phosphate physiology of vesicular-arbuscular mycorrhizas. In: Sander, F. E.; Mosse, B.; Tinker, P. B., eds. Endomycorrhizas. New York: Academic Press; 1975: 241-160.

Gerdemann, J. W. Vesicular-arbuscular mycorrhizae and plant growth. Ann. Rev. Phytopathol. 6: 397-418; 1968.

Gerdemann, J. W.; Nicholson, T. H. Spores of mycorrhizal Endogone species extracted from soil by wet sieving and decanting. Trans. British Mycol. Soc. 46: 235-237; 1963.

Giovannetti, M.; Mosse, B. An evaluation of techniques for measuring vesicular-arbuscular mycorrhizal infection in roots. New Phytologist. 84: 489-500; 1980.

Hardie, K.; Leyton, L. The influence of vesicular-arbuscular mycorrhiza on growth and water relations of red clover. I. In phosphate deficient soil. New Phytologist. 89: 599-608; 1981.

Hirrell, M. C.; Mehravaran, H.; Gerdemann, J. W. Vesicular-arbuscular mycorrhizae in the chenopodiaceae and cruciferae: do they occur? Can. J. Bot. 56: 2813-2817; 1978.

Khan, A. G. The occurrence of mycorrhizae in halophytes, hydrophytes, and xerophytes and of endogone spores in adjacent soils. J. Gen. Microbiol. 81: 7-14; 1974.

Lindsey, D. L.; Cress, W. A.; Aldon, E. F. The effects of endomycorrhizae on rabbitbrush, fourwing saltbush and corn in coal spoil material. Res. Note RM-343, Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1977. 6 p.

Malloch, D. W.; Pirozynski, K. A.; Raven, P. H. Ecological and evolutionary significance of mycorrhizal symbiosis in vascular plants (a review). Proc. Natl. Acad. Sci., USA 77: 2113-2118; 1980.

Miller, R. M. Some occurrences of vesicular-arbuscular mycorrhizae in natural and disturbed ecosystems of the Red Desert. Can. J. Bot. 57: 619-623; 1979.

Mosse, B. Advances in the study of vesicular-arbuscular mycorrhiza. Annu. Rev. Phytopathol. 11: 171-196; 1973.

Mosse, B. Vesicular-arbuscular mycorrhiza research for tropical agriculture. Honolulu: University of Hawaii Press; 1981.

Ojala, J. C.; Jarrell, W. M.; Menge, J. A.; Johnson, E. L. V. Comparison of soil phosphorus extractants as predictors of mycorrhizal dependency. Soil Sci. Soc. Am. J. 47: 958-962; 1983.

Phillips, J. M.; Hayman, D. S. Improved procedures for clearing roots and staining parasitic and vesicular-arbuscular mycorrhizal fungi for rapid assessment of infection. Trans. British Mycol. Soc. 55: 158-161; 1970.

Reeves, F. B.; Wagner, D.; Moorman, T.; Kiel, J. The role of endomycorrhizae in revegetation practices in the semi-arid west. I. A comparison of incidence of mycorrhizae in severely disturbed vs. natural environments. Am. J. Bot. 66: 6-13; 1979.

Rhodes, L. H.; Gerdemann, J. W. Nutrient translocation in vesicular-arbuscular mycorrhizae. In: Cook, C. B.; Pappas, P. W.; Rudolph, E. D., eds. Cellular interactions in symbiosis and parasitism. Columbus: Ohio State University Press; 1978: 173-195.

Rose, S. L. Mycorrhizal associations of some actinomycete nodulated nitrogen-fixing plants. Can. J. Bot. 58: 1449-1454; 1980.

Rose, S. L. Vesicular-arbuscular endomycorrhizal associations of some desert plants of Baja California. Can. J. Bot. 59: 1056-1060; 1981.

Safir, G. R.; Boyer, J. S.; Gerdemann, J. W. Nutrient status and mycorrhizal enhancement of water transport in soybean. Plant Physiol. 49: 700-703; 1972.

Staffeldt, E. E.; Vogt, K. B. Mycorrhizae of desert plants. Logan: Utah State University, U.S./I.B.P. Desert Biome Rep. 1974 Prog. 3: 63-69.

Tinker, P. B. H. Effects of vesicular-arbuscular mycorrhizas on higher plants. Symposia Soc. Exper. Biol. 29: 325-349; 1975.

Williams, S. E.; Aldon, E. F. Endomycorrhizal (vesicular-arbuscular) associations of some arid zone shrubs. Southwest Naturalist 20: 437-444; 1976.

Williams, S. E.; Wollum II, A. G.; Aldon E. F. Growth of Atriplex canescens (Pursh) Nutt. improved by formation of vesicular-arbuscular mycorrhizae. Soil Sci. Soc. Am. Proc. 38: 962-964; 1974.

In: Tiedemann, Arthur R.; McArthur, E. Durant; Stutz, Howard C.; Stevens, Richard; Johnson, Kendall L., compilers. Proceedings--symposium on the biology of Atriplex and related chenopods; 1983 May 2-6; Provo, UT. General Technical Report INT-172. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 309 p.

POTENTIAL FOR HERBICIDAL BRUSH CONTROL IN

SALT-DESERT PLANT COMMUNITIES

Greg J. Cluff, Bruce A. Roundy, Raymond A. Evans, and James A. Young

ABSTRACT: Greasewood (Sarcobatus vermiculatus (Hook.) Torr) and salt rabbitbrush (Chrysothamnus nauseosus ssp. consimilis (Greene) Hall & Clem.) are two undesirable species occupying potentially productive sites in the Great Basin. Their control, with various herbicides and mixtures of herbicides at various rates and dates, was investigated. Application of 2,4-D ((2,4-dichlorophenoxy) acetic acid) at 2 lb/acre (2.2 kg/ha) acid equivalent in June resulted in 72 and 87 percent mortality for greasewood and salt rabbitbrush, respectively. Application of picloram (4-amino-3,5,6-trichloropicolinic acid) at .5 lb/acre (.6 kg/ha) plus 2,4-D at 2 lb/acre (2.2 kg/ha) was more effective for greasewood control than 2,4-D alone in one year at very early and late dates on a xeric site. Application of 2,4-D in two successive years in June resulted in excellent control of both greasewood and salt rabbitbrush and may be necessary for effective control on xeric sites.

INTRODUCTION

Greasewood (Sarcobatus vermiculatus (Hook.) Torr) and salt rabbitbrush (Chrysothamnus nauseosus ssp. consimilis (Greene) Hall & Clem.) are dominant brush species of many saline-alkaline valley bottoms and flood plains in the Great Basin. Under pristine conditions, large areas now covered with greasewood and salt rabbitbrush supported stands of perennial native grasses such as Great Basin wildrye (Elymus cinereus Scribn. & Merr.). Because of continual overgrazing and mowing of these stands, beginning before the turn of the century, only small remnant areas of native grasses remain (Lesperance and others 1978). These areas can produce considerable forage for livestock if the brush is removed and the endemic perennial grasses are released from competition. Rehabilitated stands of native grasses can be preserved through proper grazing management (Lesperance and others 1978).

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Greasewood is a much-branched, spinescent chenopod with linear, fleshy leaves. It is usually monoecious with the staminate flowers borne spirally on terminal spikes and pistillate flowers borne in the axils of leaflike bracts (Munz 1973). Greasewood is considered a useful browse plant in some areas, but losses of livestock from oxalate poisoning occur when the shrub is eaten exclusively or in large quantities (Kingsbury 1964).

Salt rabbitbrush is one of the most common subspecies of rubber rabbitbrush (Roundy and others 1980). It is a round to pyramidal-shaped shrub in the Astereael tribe of the family Compositae, with linear leaves less than 0.04 inch (1 mm) wide and perfect flowers borne in terminal rounded cymose clusters (Munz 1973). This shrub is one of the least browsed subspecies of rabbitbrush (Hanks and others 1975).

Both greasewood and salt rabbitbrush are resprouting species, so control with fire, chaining, or brush beating is generally unsuccessful. Control of C. nauseosus with fire is very erratic, even on the same site burned at the same date in different years (Robertson and Cords 1957). Efficacy of control with fire probably depends upon whether the fire is hot enough to kill the crowns. Many greasewood and salt rabbitbrush sites are very sparse and would burn only under very hazardous fire conditions.

Greasewood and salt rabbitbrush are considered difficult to control with herbicides (Parker 1978; Roundy and others 1980). C. nauseosus is effectively controlled when new twig growth exceeds 3 to 4 inches (8 to 10 cm) (Hyder and others 1958; Mohan 1973). In drought years, C. nauseosus may not produce enough new growth to be susceptible to foliar herbicides (Hyder and others 1957). Good control of greasewood may be achieved by application of 2 lb/acre (2.2 kg/ha) 2,4-D ester or amine during active growth in the spring (Parker 1978). Simultaneous control of greasewood and salt rabbitbrush with foliar herbicides depends upon proper timing of application. Herbicides should be applied to correspond with the overlap in accelerated growth phases of the two species. The accelerated growth phases of greasewood and salt rabbitbrush overlap from the last week of May to mid-June or early July depending upon the year (Roundy and others 1980).

The purpose of this study was to determine the herbicide, rate of application, and date of application producing the most effective control of greasewood and salt rabbitbrush.

MATERIALS AND METHODS

Herbicide treatments were evaluated over a 4-year period at Surprise Valley in northeastern California and at the Gund Ranch Research and Demonstration Center in central Nevada. Greasewood and salt rabbitbrush mortality was measured at least 1 year after herbicide application in seven trials at the Gund Ranch and one trial at Surprise Valley. The soils of the Gund Ranch sites were all fine-silty, over-clayey, mixed (calcareous) mesic Aquic Durorthidic Torriorthents (U.S. Department of Agriculture, Soil Conservation Service 1978), whereas the Surprise Valley soil was a fine montmorillonitic, frigid Aquic Haplic Nadurargid.

Foliar active herbicides were applied at different times from March through August each year from 1977 to 1980. Soil active herbicides were applied in the fall and winter months each year from 1978 to 1980. In plots larger than 2.5 acres (1 ha), foliar herbicides were applied in water at 10 gal per acre (95 liters/ha) with a rangeland ground sprayer which was designed for low-volume herbicide applications (Young and others 1979). Small plot areas, less than 1.2 acre (0.5 ha), were treated at 8 gal/acre (76 liter/ha), by using a backpack sprayer with low-volume nozzles with water as the carrier. Granular herbicides were applied by hand or with a rotary spreader.

Foliar herbicide and other brush control treatments were: (a) 2,4-D low volatile ester, (b) 2,4-D plus picloram, (c) dicamba (3,6-dichloro-_o_-anisic acid), (d) 2,4-D amine (dimethylamine salt of 2,4-D), (e) triclopyr ([(3,5,6-trichloro-2-pyridinyl)oxy]acetic acid) ester, (f) silvex (2-(2,4,5-trichlorophenoxy)propionic acid), (g) 2,4,5-T (2,4,5-trichlorophenoxy)acetic acid), (h) 2,4-D ester plus 2,4,5-T, (i) 2,4-D plus dicamba, (j) 2,4-D plus dicamba plus picloram, (k) 2,4-D dormant oil (2,4-D with diesel oil carrier applied in winter), (l) rotobeating followed by 2,4-D the next season, (m) rotobeating only, and (n) spray with 2,4-D and respray the next season with 2,4-D. Granular herbicides were: (a) picloram (10 percent pellets), (b) dicamba (5 percent granules), (c) buthidazole [3(5-(1,1-dimethylethyl)-1, 3,4-thiadiazol-2-yl)-4-hydroxy-1-methyl-2-imidazolidinone] (5 percent granules), (d) tebuthiuron (_N_-[5-(1,1-dimethylethyl)-1,3,4-thiadiazol-2-yl]-N,N'-dimethylurea) (20 percent granules), and (e) karbutilate (_tert_butylcarbamic acid ester with 3-(_m_-hydroxyphenyl)-1,1-dimethylurea) (table 1).

Herbicides were applied at different rates and dates in each trial. A trial consisted of a single set of replicated treatments applied during one season on a particular site. The Gund Ranch trials differed only with respect to soil moisture conditions at the time of herbicide application. A trial was designated as relatively xeric or mesic based upon topography, growth phenology, and/or measured soil water potentials.

Greasewood and salt rabbitbrush phenology and soil water potential data were taken in trials 1, 2, 3, 5, 7, and 8 (table 1). Phenology data consisted of measurements of length and rate of elongation of new shoots. Soil water potentials were determined with thermocouple psychrometers buried 6, 18, and 36 inches (15, 45, and 90 cm) below the soil surface. Data were recorded for each date of spray.

Greasewood and salt rabbitbrush mortality was measured in each trial at least one year after treatment. Percent brush mortality in the small plots was determined by counting the total number of live and dead shrubs. In large plots, the numbers of live and dead shrubs were counted in belt transects 3 feet by 100 feet (1 m by 30 m). There were at least four small plots or belt transects for each treatment.

RESULTS AND DISCUSSION

The most consistently effective herbicide treatments for the simultaneous control of greasewood and salt rabbitbrush were: (a) 2 lb/acre (2.2 kg/ha) 2,4-D plus 0.5 lb/acre (0.6 kg/ha) picloram applied sometime from late May to July and (b) 2 lb/acre (2.2 kg/ha) 2,4-D applied sometime from late May to July (table 2). Other treatments resulted in similar control, but were not as consistent from trial to trial.

The most consistently effective herbicide treatments for greasewood control were: (a) 2 lb/acre (2.2 kg/ha) 2,4-D plus 0.5 lb/acre (0.6 kg/ha) picloram applied in June, and (b) 1 lb/acre (1.1 kg/ha) 2,4-D applied in June (table 2). Greasewood control was more effective at the low rates 1 or 2 lb/acre (1.1 or 2.2 kg/ha) of 2,4-D than the higher rate 3 lb/acre (3.4 kg/ha) (table 2). Greasewood leaves turned brown and dried within a day of 2,4-D application at 3 lb/acre (3.4 kg/ha). Greasewood appears to be hypersensitive to high rates of 2,4-D; leaves die before sufficient herbicide translocation can take place to kill the roots and stems.

The most consistently effective herbicide treatments for salt rabbitbrush control were: (a) 2 lb/acre (2.2 kg/ha) 2,4-D plus 0.5 lb/acre (0.6 kg/ha) picloram applied sometime from late May through early July, and (b) 2 lb/acre (2.2 kg/ha) 2,4-D applied in June (table 2).

Table 1.--Brush control treatments with rates and dates of herbicide application.

Trial[1]	Soil water regimes	Treatments	Rate(s)	Date(s) of application
			----Kg/ha----	-------Month/day/year---------
1	mesic	2,4-D	1.1, 2.2, 3.4	5/12, 6/1, 6/23, 7/11, 7/27/78
		2,4-D + picloram	2.2 + 0.6	5/12, 6/1, 6/23, 7/11, 7/27/78
		Silvex	3.4	6/23/78
		Triclopyr	3.4	6/23/78
		2,4-D + 2,4,5-T	3.4 (1:1 w/w)	6/23/78
		2,4-D Dormant oil	3.4	3/28/78
		Dicamba	2.2	6/23/78
		Tetuthiuron granules	0.6, 1.1	3/28/78
		Karbutilate granules	1.1, 2.2	3/28/78
		Buthidazole granules	1.1, 2.2	3/28/78
2	mesic	2,4-D	1.1, 2.2, 3.4	5/4, 5/17, 6/14, 6/28/79
		2,4-D + picloram	2.2 + 0.6	5/4, 5/17, 6/14, 6/28/79
		Silvex	3.4	6/14/79
		Triclopyr	3.4	6/14/79
		2,4-D + 2,4,5-T	3.4 (1:1 w/w)	6/14/79
		2,4-D Amine	3.4	6/14/79
		2,4,5-T	3.4	6/14/79
		Dicamba	2.2	6/14/79
		Tebuthiuron granules	0.6, 1.1	3/22/79
		Picloram pellets	0.6, 1.1, 2.2	3/22/79
		Karbutilate granules	1.1, 2.2	3/22/79
3	xeric	2,4-D	1.1, 2.2, 3.4	5/4, 5/17, 6/7, 6/14, 6/28, 7/12/79
		2,4-D + picloram	2.2 + 0.6	5/4, 5/17, 6/7, 6/14, 6/28, 7/12/79
		Silvex	3.4	6/14/79
		Triclopyr	3.4	6/14/79
		2,4-D + 2,4,5-T	3.4 (1:1 w/w)	6/14/79
		2,4-D Amine	3.4	6/14/79
		2,4,5-T	3.4	6/14/79
		Dicamba	2.2	6/14/79
4	———	2,4-D	1.1, 2.2, 3.4	6/21, 5/28/78
		2,4-D Amine	3.4	6/21/78
		2,4-D + picloram	2.2 + 0.5	6/21/78
		Dicamba	1.6, 2.2	6/21/78
5	xeric/	2,4-D	3.4	6/21-27/77
	mesic	2,4-D	1.1, 2.2, 3.4	6/13, 6/20, 6/29/78
6	———	Rotobeat 2/77 + 2,4-D	1.1, 2.2, 3.4	6/07/78
		Rotobeat 2/77 + 2,4-D	1.1, 2.2, 3.4	6/16/77, 6/07/78
		Rotobeat only	--	2/15/77
		2,4-D	1.1, 2.2, 3.4	6/07/78
		2,4-D	1.1, 2.2, 3.4	6/16/77, 6/07/78
7	mesic	2,4-D	1.4	5/22, 6/1, 6/30, 7/11, 8/01/80
		2,4-D + dicamba	1.1 (1:1 w/w)	5/22, 6/1, 6/30, 7/11, 8/01/80
		Dicamba	1.1	5/22, 6/1, 6/30, 7/11, 8/01/80
		Dicamba + 2,4-D + picloram	1.1 (4:4:1 w/w/w)	5/22, 6/1, 6/30, 7/11, 8/01/80
		Triclopyr	1.1	5/22, 6/1, 6/30, 7/11, 8/01/80
		Picloram	0.6, 1.1, 2.2	1/15/80
		Dicamba granular	0.6, 1.1, 2.2	1/15/80
8	mesic	2,4-D	2.2	6/14/79
		2,4-D + picloram	2.2 + 0.4	6/14/79
		2,4-D + dicamba	2.2 + 1.1	6/14/79

[1]Trials 1 - 7 were at the Gund Ranch, central Nevada. Trial 8 was at Surprise Valley, northeastern California.

Table 2.--Most effective treatments for the control of greasewood and salt rabbitbrush in herbicide trials conducted in central Nevada and northeast California[1].

	Greasewood				Salt rabbitbrush			
Trial	Treatment	Rate	Date	Brush mortality	Treatment	Rate	Date	Brush mortality
		Kg/ha	Mo/day/year	%		Kg/ha	Mo/day/year	%
1	2,4-D	1.1	6/01/78	96 ab	2,4-D + pic.	2.2 + 0.6	7/11/78	100
	2,4-D + pic.	2.2 + 0.6	6/01/78	88 ab	2,4-D	2.2	6/01/78	100
	Triclopyr	3.4	6/23/78	86 ab	2,4-D	3.4	6/01/78	100
2	2,4-D + pic.	2.2 + 0.6	6/14/79	94 ab	Triclopyr	3.4	6/19/79	100
	2,4-D	1.1	6/14/79	88 ab	2,4-D + pic.	2.2 + 0.6	6/28/79	92
	2,4-D + pic.	2.2 + 0.6	6/28/79	78 ac	2,4-D	2.2	6/14/79	88
	Dicamba	3.4	6/14/79	78 ac	Dicamba	3.4	6/14/79	88
3	Dicamba	2.2	6/14/79	58 cd	2,4-D + pic.	2.2 + 0.6	5/17/79	90
	2,4,5-T	3.4	6/14/79	52 d	2,4-D + pic.	2.2 + 0.6	7/12/79	86
	2,4-D + pic.	2.2 + 0.6	7/12/79	50 d	2,4-D	2.2	7/12/79	81
4	2,4-D	1.1	6/21/78	98 a	2,4-D	3.4	5/21/78	96
	2,4-D amine	3.4	6/21/78	98 a	2,4-D	2.2	6/21/78	87
	2,4-D + pic.	2.2 + 0.6	6/21/78	93 ab	2,4-D	1.1	6/21/78	84
5[2]	2,4-D	3.4	6/29/78	100 a	2,4-D	3.4	6/13/78	100
	2,4-D	1.1	6/20/78	94 ab	2,4-D	3.4	6/29/78	99
	2,4-D	2.2	6/13/78	94 ab	2,4-D	2.2	6/13/78	98
6[3]	RB + 2,4-D	1.1	6/07/78	100 a	RB + IS + 2,4-D	2.2	6/07/78	99
	IS + 2,4-D	1.1	6/07/78	100 a	IS + 2,4-D	3.4	6/07/78	98
	2,4-D	1.1	6/07/78	100 a	2,4-D	2.2	6/07/78	93
7	2,4-D + dic.	0.6 + 0.6	6/30/80	85 a	2,4-D+pic.+dic.	1.1 (4:4:1 w/w/w)	6/01/80	100
	2,4-D	1.4	7/11/80	81 ab	Dic. granules	2.2	3/80	91
8	2,4-D + pic.	2.2 + 0.4	6/14/79	96 ab	2,4-D + pic.	2.2 + 0.4	6/14/79	100
	2,4-D	2.2	6/14/79	96 ab	2,4-D	2.2	6/14/79	100

[1]Where abbreviated, picloram = pic.; dicamba = dic. Mortality figures in column followed by the same letter are not significantly different at the P = 0.1 level of confidence as determined by Duncan's multiple range test. No letters indicate no significant differences. Trials 1-7 from Nevada, 8 from California.

[2]The plot was initially sprayed with 3.4 kg/ha 2,4-D, June 25, 1977.

[3]RB = rotobeat; IS = initially sprayed with 2.2 kg/ha 2,4-D, June 16, 1977.

Other herbicide treatments that resulted in similar salt rabbitbrush control were: (a) 3 lb/acre (3.4 kg/ha) triclopyr ester applied June 14, (b) 3 lb/acre (3.4 kg/ha) 2,4-D applied in June, and (c) 2,4-D plus dicamba plus picloram (4:4:1 w/w/w) at 1 lb/acre (1.1 kg/ha) applied June 1. Generally, salt rabbitbrush was easier to control than greasewood (tables 2,3,4).

Foliar-applied herbicides were generally more effective than soil-applied herbicides for brush control. Dicamba granules applied at 2 lb/acre (2.2 kg/ha) in March controlled 91 percent of the salt rabbitbrush in trial 7 (table 2), but no soil herbicides controlled more than 27 percent of the greasewood. The permeability of the soil in the experimental area is very slow (Summerfield and Bagley 1974; U.S. Department of Agriculture, Soil Conservation Service 1978), which may account for the relative ineffectiveness of the soil-applied herbicides.

Rotobeating alone only killed 11 and 17 percent of the greasewood and salt rabbitbrush, respectively. Many shrubs resprouted vigorously the year following rotobeating or spraying with a herbicide which had resulted in poor control. Roundy and others (1980) showed that greasewood growth was accelerated the following year on shrubs sprayed with herbicides but not killed. They hypothesized that respraying greasewood a second season would greatly enhance brush mortality because of the increased growth rate of the new shoots of surviving plants. Results from trial 5 support this theory (table 2). Trial 5 was initially sprayed with 3 lb/acre (3.4 kg/ha) 2,4-D in June 1977. Only 30 percent of the greasewood was killed. It was resprayed with 1, 2 and 3 lb/acre (1.1, 2.2, and 3.4 kg/ha) 2,4-D in June 1978. The 3 lb/acre (3.4 kg/ha) rate applied in mid-June killed all of the remaining greasewood, indicating much better control.

Available soil moisture at time of herbicide application greatly affected control of greasewood and salt rabbitbrush. Trial 8 was a very wet site in northeastern California which received tail water from irrigated fields (U.S. Department of Agriculture, Soil Conservation Service 1978). Greasewood and salt rabbitbrush control averaged 98 percent with all herbicide treatments (table 2). At the Gund Ranch, trial 2 was a fairly mesic site during the year of herbicide application, whereas trial 3 was a xeric site. Soil water potentials at 18 inches (45 cm) averaged -0.07 and -2 M pascals on trials 2 and 3, respectively, during the herbicide application period. As a result, the total leader growth and growth rate of both greasewood and salt rabbitbrush was less in trial 3 than trial 2 (fig. 1). This translated into significantly ($P = 0.1$) lower greasewood control in trial 3. Maximum brush control achieved was 94 and 58 percent for greasewood and 100 and 90 percent for salt rabbitbrush in trials 2 and 3, respectively (table 2).

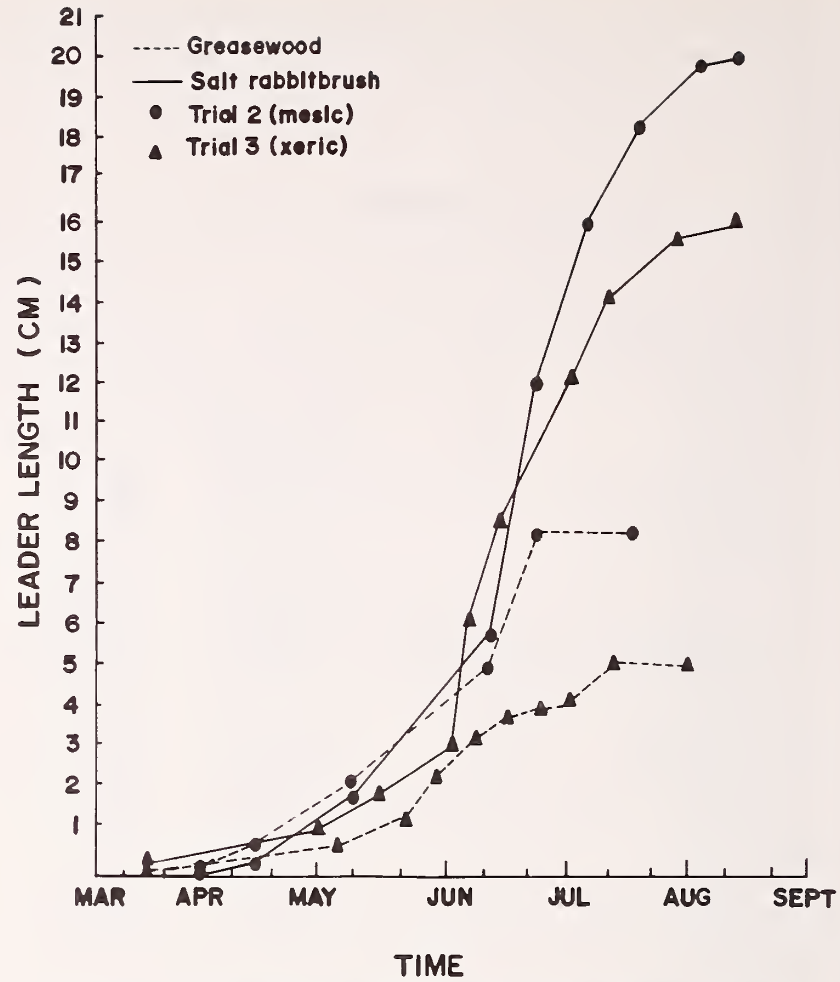

Figure 1.--Leader length (cm) of greasewood and salt rabbitbrush in mesic trial 2 and xeric trial 3.

There was a trend toward greater brush control with higher rates of 2,4-D in the xeric trial, but not in the mesic trial. This probably resulted because of the poor greasewood control on xeric trial 3, consequently most of the brush mortality was salt rabbitbrush in that trial (table 4).

Control of greasewood was more affected by xeric conditions than control of salt rabbitbrush. In mesic trial 2, average greasewood mortality was 39 percent and salt rabbitbrush mortality was 52 percent. In more xeric trial 3, greasewood and salt rabbitbrush mortality averaged 10 and 53 percent, respectively (table 4). Greasewood control was reduced almost 30 percent because of xeric conditions, whereas salt rabbitbrush was not affected ($P = 0.1$).

Timing of herbicide application was an important factor in obtaining good brush control. In general, best control of greasewood and salt rabbitbrush was obtained when herbicides were applied sometime from the last of May through June (table 3). The overlap in the accelerated growth phases of greasewood and salt rabbitbrush in some years is from the last week of May to mid-June (Roundy and others 1980). Accelerated growth as used here means a growth rate of new shoots of at least 0.04 inch per day (1 mm/day). This period correlates well with the dates of herbicide application that resulted in the highest brush mortality (table 3).

Table 3.--Response of greasewood and salt rabbitbrush (percent brush mortality) to herbicide application in trials conducted in central Nevada[1].

Trial	May 4	May 12	May 17	May 22	June 1	June 7	June 14	June 21	June 28	July 11	July 27	August 1
	Percent											
1												
Greasewood		36d			71a			66ab		62ac	47cd	
Salt rabbitbrush		39ef			96a			90a		55ce	47df	
2												
Greasewood	35bc		18c				84a		25bc			
Salt rabbitbrush	44b		17c				69a		69a			
3												
Greasewood	2b		6ab			20ab	29a		3b	2b		
Salt rabbitbrush	59a		48b			53ab	62a		64a	61a		
4												
Greasewood								95a	81b			
Salt rabbitbrush								89a	50b			
5												
Greasewood							95a	92ab	90ab			
Salt rabbitbrush							91a	88a	76b			
7												
Greasewood				65a	55ab				50ab	50ab		39b
Salt rabbitbrush				60ab	78a				60ab	47ab		39b

[1]Row means followed by the same letter are not significantly different at the P = 0.1 level of confidence as determined by Duncan's multiple range test.

Table 4.--Comparison of effectiveness of brush control with 2,4-D in mesic trial 2 and xeric trial 3 in a typical greasewood-salt rabbitbrush community in central Nevada[1].

	Brush mortality (%)						
	Date Month/day				Rate Kg/ha		
Trial	5/4	5/17	6/14	6/28	1.1	2.2	3.4
2 (mesic)							
Salt rabbitbrush	44ee	17fh	77a	69ab	54ab	48ac	53ab
Greasewood	35df	18fh	76a	25eg	39bc	34c	43bc
3 (xeric)							
Salt rabbitbrush	34df	50bd	62ac	64ab	42bc	55ab	61a
Greasewood	2h	6gh	29ef	3h	7d	13d	10d

[1]Row and column means of each variable (rate and date) followed by the same letter are not significantly different at the P = 0.1 level of probability as determined by Duncan's multiple range test.

The date of herbicide application which resulted in the highest simultaneous control of greasewood and salt rabbitbrush in trials 2 and 3 was June 14 (table 4). This correlated with times of accelerated growth for salt rabbitbrush in trials 2 and 3 and for greasewood in trial 2. Greasewood in trial 3 never exhibited an accelerated growth phase which may account for the low mortality of greasewood in that trial (fig. 1; table 4). Greasewood does not obtain the leader lengths of salt rabbitbrush (Roundy and others 1980) (fig. 1). This is one reason why greasewood is generally

harder to kill than salt rabbitbrush. If all other factors are equal, greasewood does not have the herbicide-absorbing area of salt rabbitbrush. Greasewood also exhibited a shorter time span than salt rabbitbrush in which optimum control could be obtained (table 3). This is probably because greasewood starts accelerated growth in late May with salt rabbitbrush, but ceases by July, whereas salt rabbitbrush continues until August (Roundy and others 1980).

In contrast to other reports (Hyder and others 1958; Mohan 1973), 3 to 4 inches (8 to 10 cm) of leader length may not be necessary to obtain good rabbitbrush control. The salt rabbitbrush in trials 2 and 3 did not attain that leader length until around June 10 (fig. 1). There were two spray dates before June 10 and two spray dates after June 10. Salt rabbitbrush control averaged 27 and 50 percent in trial 2, and 41 and 63 percent in trial 3 before and after June 10, respectively. These results indicate that brush mortality was higher after leader length exceeded 3 inches (8 cm). However, leader growth rate was also greater after June 10 so this could account for greater brush mortality. Herbicide applications in August did not control more than 40 percent of the salt rabbitbrush (table 3), yet average leader length exceeded 3 inches (8 cm). In trial 1 best control of salt rabbitbrush (96 percent) was obtained when 2,4-D was applied on June 1 when average leader length was only 1.5 inches (4 cm). An average leader length of 1.5 inches (4 cm) indicates that accelerated growth of salt rabbitbrush is under way. First opening of the flower buds is correlated with growth cessation (Roundy and others 1980). Foliar herbicides should be applied to salt rabbitbrush after the average leader length reaches 1.5 inches (4 cm) and before first opening of flower buds in order to achieve optimum control.

Based on results of this study, the brush control treatment with the highest probability of achieving optimum, simultaneous control of greasewood and salt rabbitbrush is 2 lb/acre (2.2 kg/ha) 2,4-D or 2 lb/acre (2.2 kg/ha) 2,4-D plus 0.5 lb/acre (0.6 kg/ha) picloram applied as a foliar spray sometime from the last of May through June. The addition of 0.5 lb/acre (0.6 kg/ha) picloram increased brush mortality ($P = 0.1$) in some trials (table 2). Under xeric conditions, such as in trial 3, it might be necessary to spray in two consecutive years to achieve good brush control.

PUBLICATIONS CITED

Hanks, D. L.; McArthur, E. D.; Plummer, A. P.; Guinta, B. C.; Blauer, A. C. Chromatographic recognition of some palatable and unpalatable subspecies of rubber rabbitbrush in and around Utah. J. Range. Manage. 28: 144-148; 1975.

Hyder, D. N.; Sneva, F. A.; Chilcote, D. O.; Furtick, W. R.. Chemical control of rabbitbrush. Res. Progress Rep. Western Weed Control Conf., 1957; 46-47.

Hyder, D. N.; Sneva, F. A.; Chilcote, D. O.; Furtick, W. R. Chemical control of rabbitbrush with emphasis on simultaneous control of big sagebrush. Weeds. 6: 289-297; 1958.

Kingsbury, J. M. Poisonous plants of the United States and Canada. New Jersey: Prentice-Hall; 1964. 626 p.

Lesperance, A. L.; Young, J. A.; Eckert, R. E., Jr.; Evans, R. A. Great Basin wildrye. Rangeman's J. 5: 125-127; 1978.

Mohan, J. M. 14 years of rabbitbrush control in central Oregon. J. Range Manage. 26: 448-451; 1973.

Munz, P. A. A California flora and supplement. Los Angeles: University of California Press; 1973. 1904 p.

Parker, K. G. Range plant control-modernized. Circular 346 (revised). Logan, UT: Utah Agriculture Extension Service; 1978. 17 p.

Robertson, J. H.; Cords, M. P. Survival of rabbitbrush <u>Chrysothamnus</u> spp., following chemical, burning, and mechanical treatments. J. Range Manage. 10: 83-89; 1957.

Roundy, B. A.; Young, J. A.; Evans, R. A. Phenology of salt rabbitbrush and greasewood. Weed Sci. 29: 448-454; 1980.

Summerfield, H. B.; Bagley, D. G. Soil survey of Surprise Valley. Home Camp Area, California-Nevada. Washington, DC: U.S. Department of Agriculture, Soil Conservation Service; 1974. 130 p. and maps.

U.S. Department of Agriculture, Soil Conservation Service. Advance soil survey data - Gund Ranch - Eureka and Lander Counties, Nevada. Washington, DC: U.S. Department of Agriculture, Soil Conservation Service; 1978. 62 p.

Young, J. A.; Roundy, B. A.; Bruner, A. D.; Evans, R. A. Ground sprayers for sagebrush rangelands. Advances in Agricultural Technology Western Series, No. 8. Washington, DC: U.S. Department of Agriculture, Agricultural Research Service; 1979. 13 p.

In: Tiedemann, Arthur R.; McArthur, E. Durant; Stutz, Howard C.; Stevens, Richard; Johnson, Kendall L., compilers. Proceedings--symposium on the biology of <u>Atriplex</u> and related chenopods; 1983 May 2-6; Provo, UT. General Technical Report INT-172. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 309 p.

ATRIPLEX/GRASS AND FORB RELATIONSHIPS UNDER NO GRAZING AND SHIFTING PRECIPITATION PATTERNS IN NORTH-CENTRAL WYOMING

Herbert G. Fisser and Linda A. Joyce

ABSTRACT: Analysis of long-term vegetation records on three saltbush (Atriplex gardneri [Moq.] D. Dietr.) exclosure sites in the Big Horn Basin of Wyoming demonstrated significant changes in community composition. Within a total community responsive only to precipitation, there was a simultaneous increase in grasses and decrease in shrubs. Seasonal precipitation was also changing during the 1963 to 1978 period, with decreases in spring precipitation and increases in winter precipitation. Analyses of the relationship between precipitation and standing crop demonstrated that this relationship was significantly affected by the changing community dynamics. The response of the saltbush community to precipitation dynamics was much greater when the herbaceous component was more than 50 percent of the total standing crop. Greatest water use efficiency was demonstrated when community components strongly shifted toward herbaceous species.

INTRODUCTION

Climate/vegetation relationships have long been of interest in the semi-arid regions of the western United States (Craddock and Forsling 1938; Smoliak 1956; Wight and Hanks 1981). Wide weather fluctuations and the resultant variability in vegetation production have large impacts on animal production. Understanding the long-term relationships between weather and forage availability could provide valuable interpretive tools for the management of these lands.

The objectives of this paper were to: (1) document a 25-year grazing and research program in the Big Horn Basin; (2) investigate the vegetation response of low condition range to protection from grazing; and (3) quantitatively describe standing crop and precipitation relationships of the saltbush community.

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REGIONAL HISTORY AND ECOLOGICAL RESEARCH

The Big Horn Basin comprises some 8 million acres (3.2 million ha) in north-central Wyoming. Much of the area is classified in the 5-to 9-inch (13-to 23-cm) annual precipitation zone by the Soil Conservation Service (1966). Precipitation levels increase near the mountains (Shrader 1978). Chenopod vegetation, including greasewood (Sarcobatus vermiculatus [Hook.] Torr.), winterfat (Ceratoides lanata [Pursh] J. T. Howell), and hopsage (Grayia spinosa [Hook.] Moq.), occurs in large expanses and provides a base for winter livestock grazing (Bindschadler 1948; Fisser and others 1979). The most common chenopod of the Big Horn Basin is Gardner saltbush (Atriplex gardneri [Moq.] D. Diet.). It occurs on areas of poorly developed alkaline, often sodic, and usually silty soils (Vosler 1962). Low winter snow cover in the Basin provides ideal winter sheep grazing (King 1959; Shrader 1978).

Important climatic differences exist between the Big Horn Basin and similar grazing areas west of the Continental Divide. The similarities are obvious: saline soil, low precipitation, warm summer temperatures, and cold winters. Dissimilarities involve a relatively even distribution of precipitation in the Great Basin compared to a concentration of moisture during late spring in the Big Horn Basin. Associated with spring moisture is a later but very accelerated warm-up which, in the Big Horn Basin, produces a climate unlike the semi-mediterranean climate of the Great Basin (Daubenmire 1968).

From the late 1880's into the 1920's vast herds of sheep and cattle indiscriminately utilized the Big Horn Basin (Duhig 1948). Excessive and continuous use severely depleted perennial vegetation, similar to the impacts on winter rangeland grazing areas in Idaho and Utah (Frink 1954).

With the introduction and terrifying epidemic explosion of halogeton (Halogeton glomeratus (C. A. Mey. in Ledeb.) in the 1930's (Palmer 1955), a contagious hysteria gripped the West including Wyoming's Little Colorado and Red Desert areas, and the Big Horn Basin (Erickson and others 1951; Cook and Stoddard 1953; Sharp 1954; Bohmont and others 1955). The image of rangelands totally dominated by the annual invader and the

possibility of losses of thousands of livestock overnight all sparked a revolution of concern for arid lands, especially in Wyoming (Rauchfuss and others 1957; Morton and others 1959; Bruner and Robertson 1963). The Bureau of Land Management was allocated many millions of dollars to find ways to eradicate and destroy the exotic invader. A few can yet recall the rather senseless chemical spray control activities (Palmer and others 1955). Reason did prevail, however, and ecologically oriented research was developed by such leaders as Larry Stoddard and Wayne Cook in Utah, Joe Robertson in Nevada, and Ed Tisdale and Lee Sharp in Idaho (Frischknecht 1967).

DRY CREEK GRAZING INTENSITY STUDY

Grazing Study Origin and Methodology

When halogeton was found in the Big Horn Basin, funding by the Department of the Interior was quickly allocated to initiate ecological evaluation and conduct grazing intensity studies. The University of Wyoming with Alan Beetle, Bob Lang, and Dixie Smith then entered the fray. The Dry Creek Halogeton Pasture Study near Greybull was initiated in 1956 (fig. 1). Some may even recall the BLM-sponsored range weed control tour to that grazing unit during the summer of 1961. The group observed vegetation response to protection from grazing and to three levels of winter utilization intensity, 20, 40, and 80 percent removal of saltbush annual production. At that time, after five years of controlled grazing, data were inconclusive, with greater variation exhibited among pastures of similar use than those of dissimilar use. To alleviate the problem, grazing and vegetation sampling procedures were modified. A band of 1,800 ewes was obtained instead of the previous 200, vegetation sampling was stratified to include only saltbush vegetation, and an additional pair of pastures with an allocated 30 percent saltbush removal rate was attained by division of the existing 20 percent removal units (fig. 2) (Fisser and Wight 1965).

Area cover, herbage production, and precipitation were measured at each exclosure. Twenty 1-foot by 10-foot (0.3-m x 3.0-m) plots were located systematically along a randomly located 100-foot (30-m) steel tape. Each plot was subsampled for vegetative cover using 10 1-foot by 1-foot (30-cm x 30 cm) subplots. Percent area cover of all herbaceous semiwoody and woody species was estimated within each subplot. Standing crop was determined by clipping herbaceous species at ground or crown level at approximately peak community standing crop each year. Saltbush was treated as a herbaceous species with new growth clipped at the sampling time. All clippings were oven-dried at 160°F (70°C) for 24 hours prior to weighing.

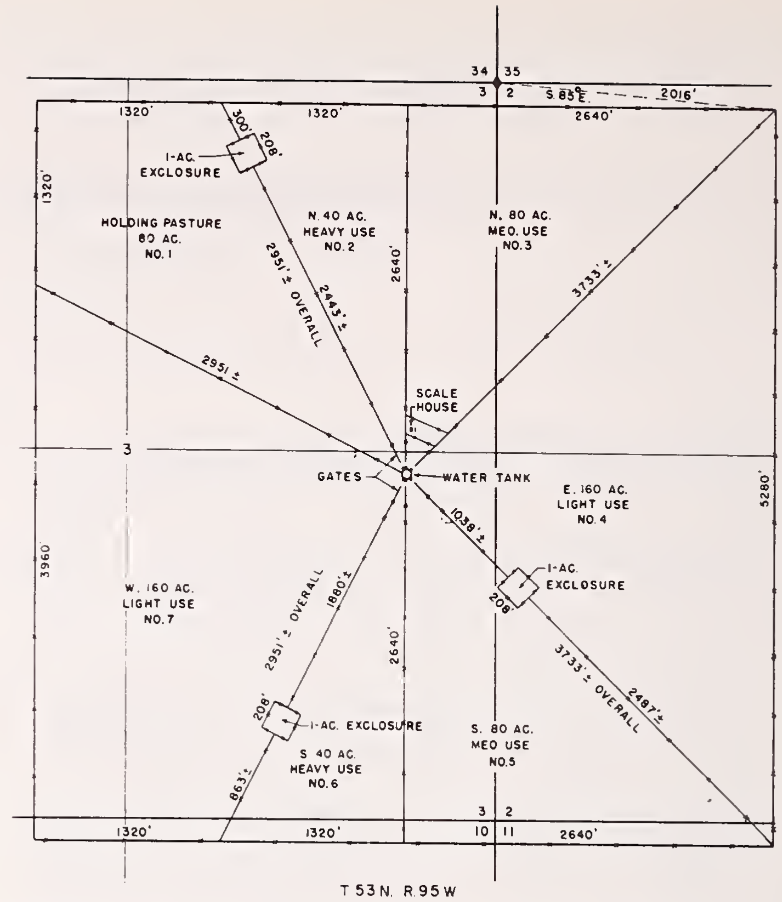

Figure 1.--The 640-acre Dry Creek Halogeton Research Pasture system which was constructed in 1955 and located 10 miles Northeast of Greybull, Wyo., in the Big Horn Basin (dimensions 1 mile by 1 mile).

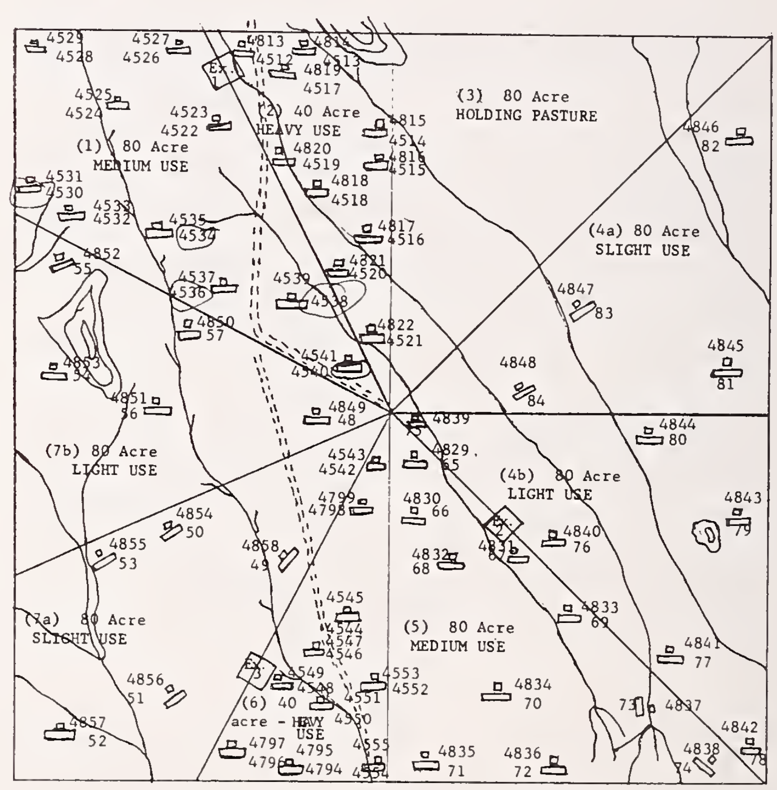

Figure 2.--Dry Creek Halogeton Pasture system showing the modified fencing for the 30 percent saltbush utilization pastures and locations of permanent quadrats for shrub mapping (2 ft by 20 ft) and herbaceous cover (4 ft by 4 ft) by point hit procedures.

Precipitation was recorded on site four times a year with simple aluminum rain gauges: April 15, July 1, September 1, and October 15. Oil was added after each reading to prevent evaporation, and during the winter months antifreeze was added in known amounts to prevent the gauges from freezing and breaking.

Grazing Study Summary

In 1956 and 1957, within the 640-acre (260-ha) unit, halogeton occurred only in small areas at the locations shown in black in figure 3. By 1960 halogeton was distributed over all the pastures (fig. 4) and by 1965 its abundance was clearly shown to be related to grazing intensity (table 1 and fig. 4) (Fisser and others 1966). In 1967, the grazing study was terminated since it was patently obvious, as noted by others (Frischknecht 1967; James and Cronin 1974), that halogeton was disturbance-dependent. Even with total native vegetation cover of only 10 to 13 percent, essentially all contributed by Gardner saltbush, the exotic annual was unable to invade in amounts adequate to pose a threat to the ecological systems, or to the grazing animals when the saltbush was grazed at slight to moderate stocking levels (Fisser and Steger 1967). Significant response of Gardner saltbush to differential grazing intensity was apparent. Interpretive evaluation of winter grazing stress suggested that 35 percent saltbush removal was acceptable for maintenance of the shrub populations (fig. 5). Halogeton populations in the exclosures were similar to those of the slight-use pastures with a density of less than two plants per square foot. Abundance was almost eight times greater in the heavy-use (80 percent) pastures (table 1).

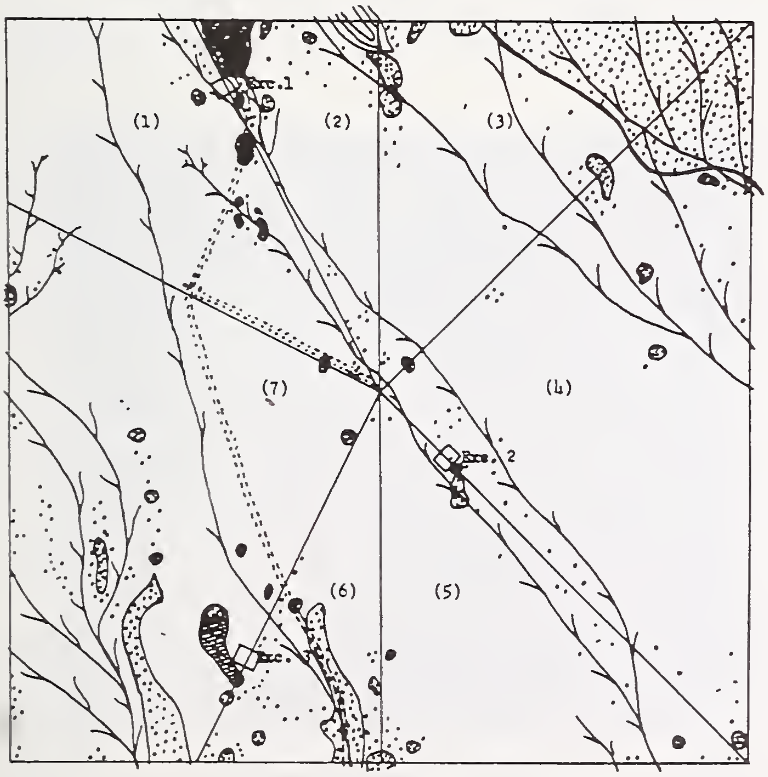

Figure 3.--Distribution of halogeton within the Dry Creek Halogeton Pastures during 1956-1957.

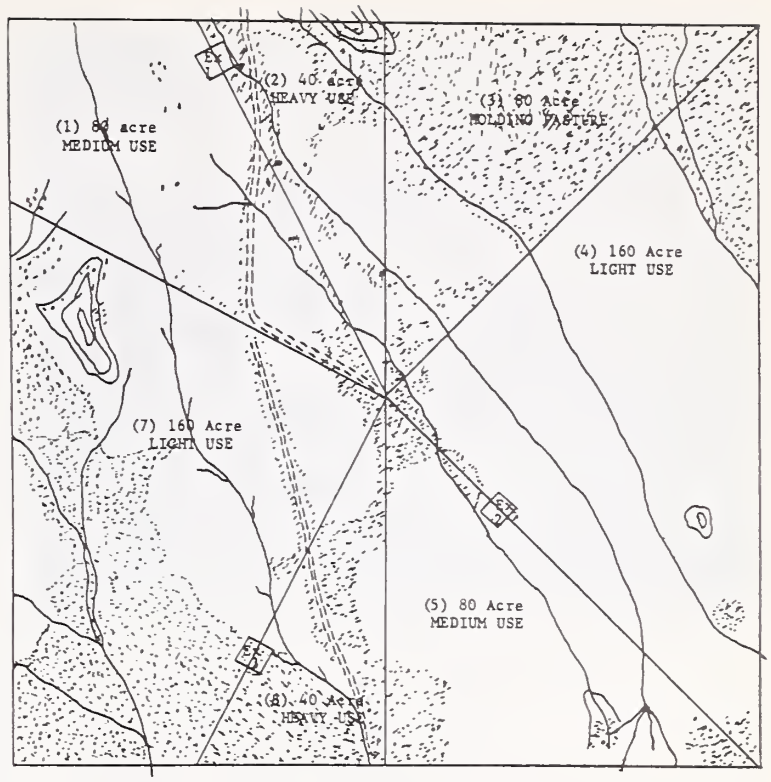

Figure 4.--Distribution of halogeton within the Dry Creek Halogeton Pastures during 1960.

Table 1.--Density of halogeton in 1964 and 1965 as related to grazing utilization intensity.

Intensity of use	Average no. of plants per square foot 1964	1965
Slight (20 percent)	1.0	1.7
Light (30 percent)	1.8	2.4
Moderate (40 percent)	2.0	3.1
Heavy (80 percent)	7.5	13.3

During the 1962 field season, the Arid Land Ecology Research Program was expanded to monitor exclosure vegetation in a wide variety of vegetation types in Wyoming. The objectives of the monitoring program were multiple; the sampling scheme was the same one used in the halogeton study in Dry Creek (Fisser and Hamner 1963). Study of the exclosure vegetation continued beyond the termination of the grazing study in 1967, annually through 1983.

Figure 5.--Compare the uniform texture apparent in the heavy use (80 percent) pasture to the slight use (20 percent) pasture to the left, exclosure 3 on the fence line, and the open native range in the foreground. This 1966 oblique aerial photograph of the Dry Creek Grazing Intensity pastures shows the results of severe overuse of Gardner saltbush.

VEGETATION/PRECIPITATION INTERPRETIVE ANALYSES

Methods

Standing crop and precipitation data were monitored inside the exclosures over the 1963 to 1983 period. Field collection is still ongoing. For this study, only 1963 to 1978 data were used. Standing crop data were summarized into plant groups on an annual basis from the original field sheets and the annual reports of the Arid Land Ecology Research Program (Fisser and others 1980).

Long-term records of annual precipitation were obtained from the nearby U.S. Weather Station at Basin, Wyo., to determine if the climate was undergoing any significant long-term wet or dry cycles. The period 1940 to 1978 was used and a 7-year moving average was compiled to smooth annual variation. For purposes of comparison, the onsite seasonal precipitation and standing crop data were also smoothed using a 7-year moving average.

Analyses

Several analyses were made with the onsite data. To determine whether vegetation compositional changes were occurring, an index of vegetation composition was calculated by dividing grass and forb standing crop by total standing crop each year at each site. If grass and forb standing crop were increasing either from protection from grazing or climate changes, the index would increase. If no changes were occurring, the index would fluctuate randomly or with seasonal precipitation.

The long-term relationship between seasonal precipitation and standing crop was examined using correlation analysis. As the entire community was sampled, the relationship of plant groups within the community and precipitation could also be examined.

RESULTS AND DISCUSSION

Vegetation Dynamics

In 1963, standing crop was still predominantly Gardner saltbush, even after 7 years of protection from grazing (table 2) (Fisser and Hamner 1963). Grass was very sparse and only in exclosure #1 were forbs composing 8 percent of the standing crops, a significant component. The grass species present in the exclosures were bottlebrush squirreltail (Sitanion hystrix [Nutt] J. G. Sm.) and Sandberg bluegrass (Poa secunda [Presl]). The absence of associated species in the wet year of 1964 can be noted from the photograph of exclosure 2 (fig. 6).

Table 2.--Percent biomass composition inside halogeton exclosures in 1963 and 1979.

Exclosure	1963			1979		
	Grass	Forb	ATGA[1]	Grass	Forb	ATGA
1	1	8	91	34	4	62
2	<1	1	98	51	1	48
3	<1	1	99	46	5	49

[1] ATGA = Atriplex gardneri

Figure 6.--Gardner saltbush vegetation inside exclosure 2 at time of herbage production sampling in 1964. Note almost total monoculture dominance by saltbush.

Sixteen years later, in 1979, a significant change in community composition was apparent (table 2) (Fisser and others 1980). Grass standing crop constituted 34, 51, and 46 percent of total standing crop in exclosures 1, 2, and 3, respectively. Gardner saltbush reflected this increase in grass standing crop by decreasing to 62, 48, and 49 percent of the total standing crop (fig. 7). Forb standing crop remained a small component of the community. The species of grass present in the exclosures after sixteen years of protection were the same species recorded in 1963. Annual and perennial forb species did increase in total numbers although the standing crop remained very small. Thus, the increase in grass standing crop represents an increase in the same species found in 1963 rather than an increase in the diversity of grass species found at these exclosures.

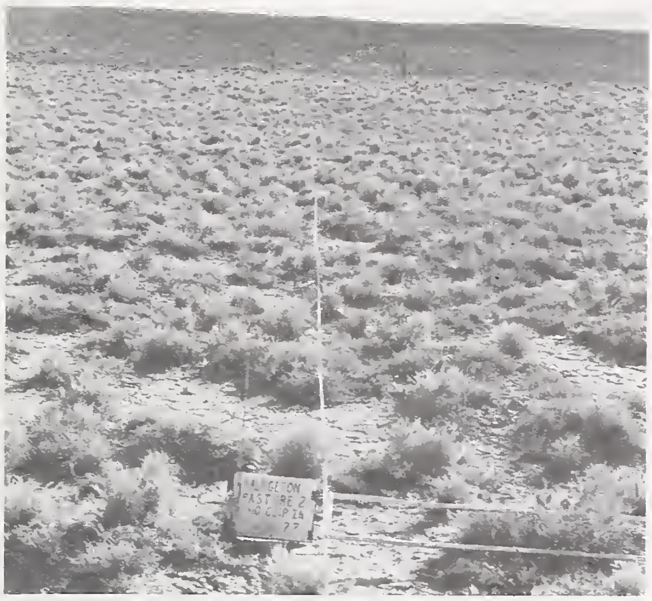

Figure 7.--Mixed grass (bottlebrush squirreltail) and shrub (Gardner saltbush) inside exclosure 2 in 1979.

The change in community composition was seen in the steady increase of the index of vegetation composition at each exclosure (fig. 8).

A steady change in the dynamics of total standing crop would affect the results of this index. In this study, however, the annual herbage production fluctuations were large. Total standing crop was, consequently, not significantly correlated with time, but was significantly correlated with precipitation (r = .67). No consistent increase associated with protection from grazing was found. Thus, the index of vegetation composition expressed the shifting changes in those intracommunity compositional dynamics.

Differences in the pattern of the community index among exclosures reflect soil and topographic differences (fig. 8). Exclosure 1 was the least productive because of limiting soils and it exhibited the longest delayed increase of the index of vegetation. Exclosure 3 was most typical of the Big Horn Basin's vast areas of silty soils and little relief. Exclosure 2 was a silty site which often received runon water. The index for that site demonstrated the earliest, greatest, and most dynamic increase.

Precipitation Dynamics

Precipitation was not recorded at the halogeton exclosures until 1960. For comparative purposes, the annual precipitation records for 1940 through 1982 from the nearby U.S. Weather Station at Basin, Wyo., were smoothed by application of a 7-year moving average (fig. 9). Annual precipitation records from Basin reflected a dry period during the 1950's and increased annual moisture into the mid-1960's. The Dry Creek halogeton grazing intensity studies thus were initiated near the time that annual precipitation began an increasing trend. A decreasing trend during the late 1960's and early 1970's is also apparent (fig. 9). Inspection of annual precipitation values recorded at the Dry Creek Pastures during the 1960's reveals trends similar to those noted at Basin, Wyo.

By segregating seasonal moisture values at the exclosures in the grazing intensity pastures, seasonal trends were found. While the annual change was downward, winter precipitation increased greatly and the combined values for summer and fall also increased (fig. 10). The downward trend of total annual precipitation thus occurred as a result of decreasing spring precipitation, the largest individual moisture component contributing to total annual precipitation at these sites.

Vegetation/Precipitation Interaction

Vegetation portrays the biotic response environmental factors. In semiarid regions, soil, precipitation, and temperature can readily be identified as controlling influences. Successional changes in the arid regions are slow. Previous research has shown that climatic effects usually dominate vegetation dynamics and rates of change that are induced by management effects (Reed and Peterson 1961; Hastings and Turner 1965; Lewis and others 1965).

At the Dry Creek grazing intensity pastures, seasonal precipitation trends were reflected by the changing dynamics of the plant community. The consistent increase in the community index reflected a similar increase in the 7-year moving average of grass and forb standing crop and the concomitant decrease in the shrub component. Using the 7-year moving average for comparison, shrubs decreased over the period 1963 through 1971 and grasses and forbs increased (fig. 10).

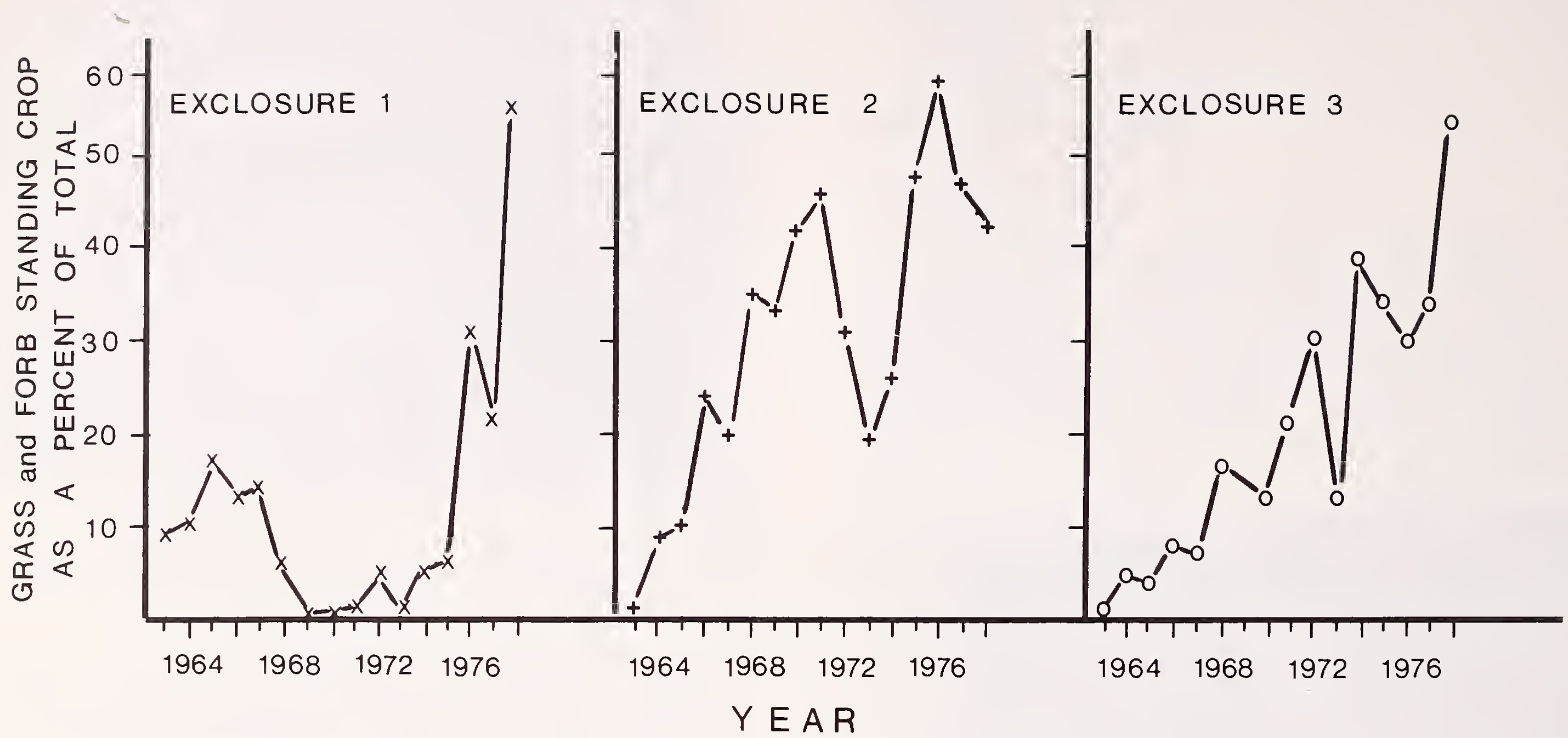

Figure 8.--Community index at saltbush sites in Wyoming. This index is the ratio of grass and forb standing crop to total standing crop.

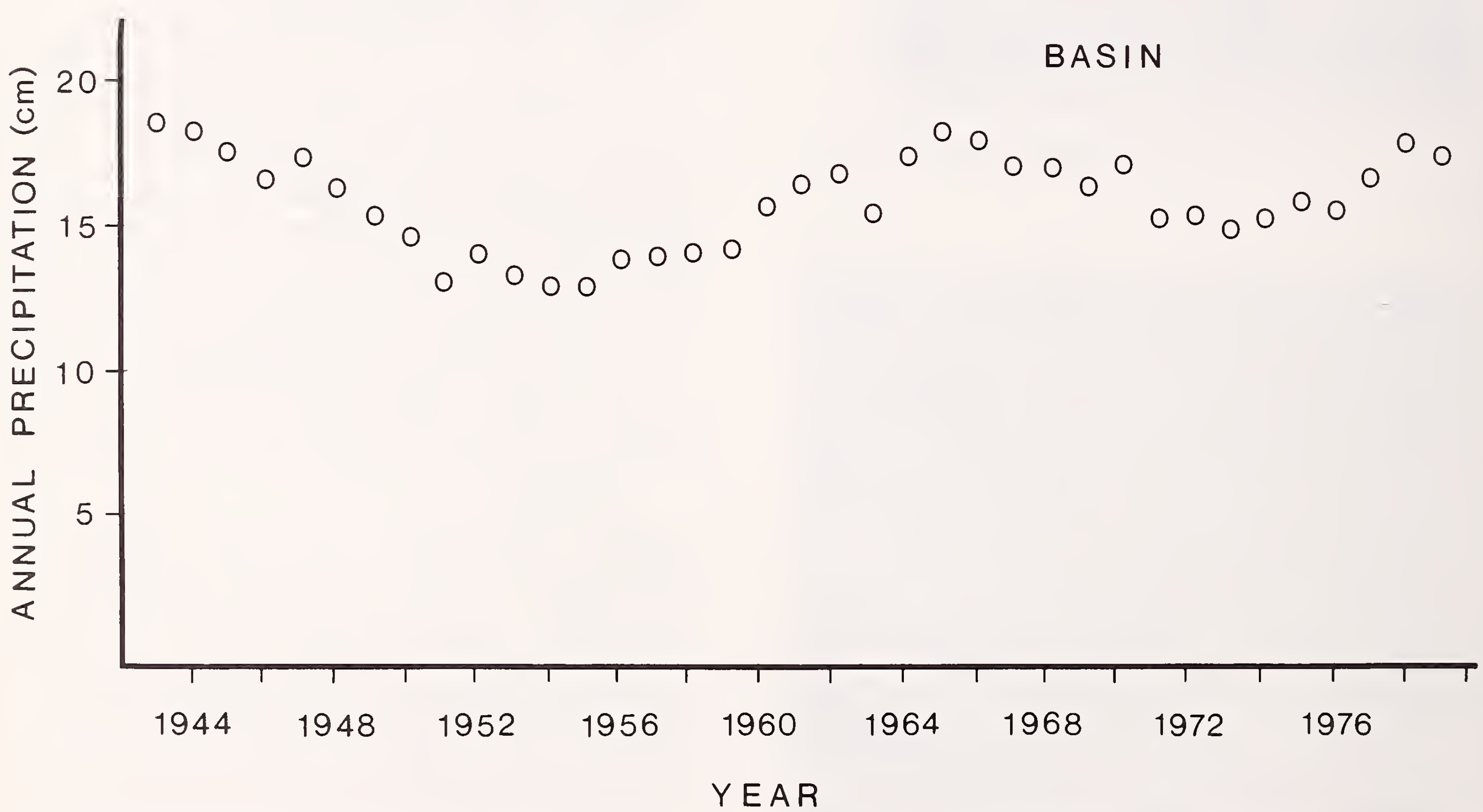

Figure 9.--Smoothed 7-year averages from 1940 through 1980 of annual precipitation at the Basin, Wyo., U.S. Weather Service Station.

Total standing crop, reflecting the declining dominance of saltbush, decreased through 1971. Saltbush continued to decrease during subsequent years in conjunction with the increases of grasses and forbs (fig. 10). Trends shown for halogeton exclosure 2 were representative of all. Each of these sites was released from grazing in the mid 1950's. Community composition changes thus appear to have been most strongly influenced by protection from grazing during the early years. With condition class improvement through the 1960's, dynamic response to annual precipitation variation became increasingly evident (fig. 10).

Long-term Relationships

Based on analysis of data from seven saltbush exclosures in the Big Horn Basin, including the halogeton sites, individual plant groups were correlated with different precipitation periods (Joyce 1981). Grass and forb standing crop was significantly correlated with winter precipitation; shrubs were significantly correlated with spring precipitation at each site (table 3). In addition, grass and forb standing crop tended not to be correlated with spring precipitation. Similarly, shrubs were not correlated with winter precipitation. These plant groups exhibited temporal separation in terms of precipitation dependence.

No plant group was correlated with the previous fall's precipitation. The correlation coefficients, while not significant, did consistently have a negative sign, however, indicating a possible negative relationship between the previous fall's precipitation and shrub standing crop. This contrasted with the findings of Blaisdell (1958) and may well represent variations attributable to the regional climatic differences noted previously. Total standing crop was significantly correlated with spring precipitation and with the sum of winter and spring precipitation, reflecting the composite results of the individual plant group analyses.

These correlation patterns reflected seasonal precipitation trends. Increasing grass and forb standing crop was correlated with winter plus spring precipitation which was also increasing (fig. 11). It may be that spring moisture was not available for use by the early maturing bottlebush squirreltail and sandberg bluegrass and that the changing patterns in seasonal precipitation benefited the winter precipitation dependent grasses, but put at a disadvantage the spring precipitation dependent shrubs.

Long-term records of exclosures such as these have often been used to develop predictive equations for range forage (Smoliak 1956) or to assess water use efficiency on grasslands and shrublands (Webb and others 1978). Community composition shifts are often not accounted for in these equations of total standing crop. The index of vegetation composition demonstrated a steady increase at each exclosure, although the pattern varied (fig. 8). At exclosure 2, the index increased steadily, decreased in a dry year, and fluctuated in the remaining years. If the first segment represents a continual shift, irrespective of fluctuations in total standing crop, then the break could indicate a stabilization of the intra-community dynamics. To test this theory, the entire time span was divided into two periods: 1963 through 1971 and 1972 through 1978. The relationship between standing crop and seasonal precipitation was examined within each time period at exclosure 2.

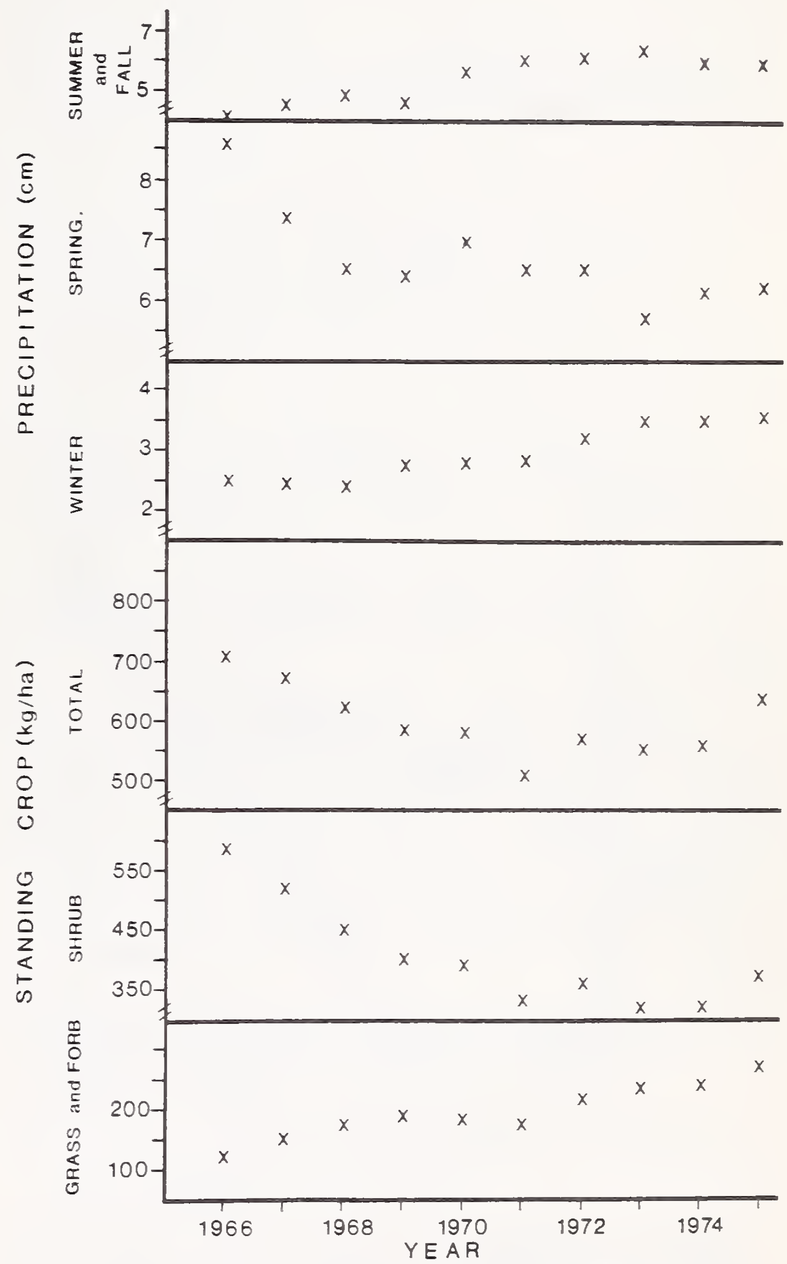

Figure 10.--Smoothed 7-year moving averages of seasonal precipitation and standing crop at halogeton exclosure 2 for 1964 through 1978, respectively.

Table 3.--General pattern of relationship between precipitation distribution and standing crop inside saltbush exclosures.

Precipitation	Vegetation component: Grass and forb	Shrub	Total
Fall	NS[1]	NS	NS
Winter	+[2]	NS	NS
Spring	NS	+	+
Winter plus spring	NS	+	+

[1] NS - not significant

[2] + - significant $p \leq .05$

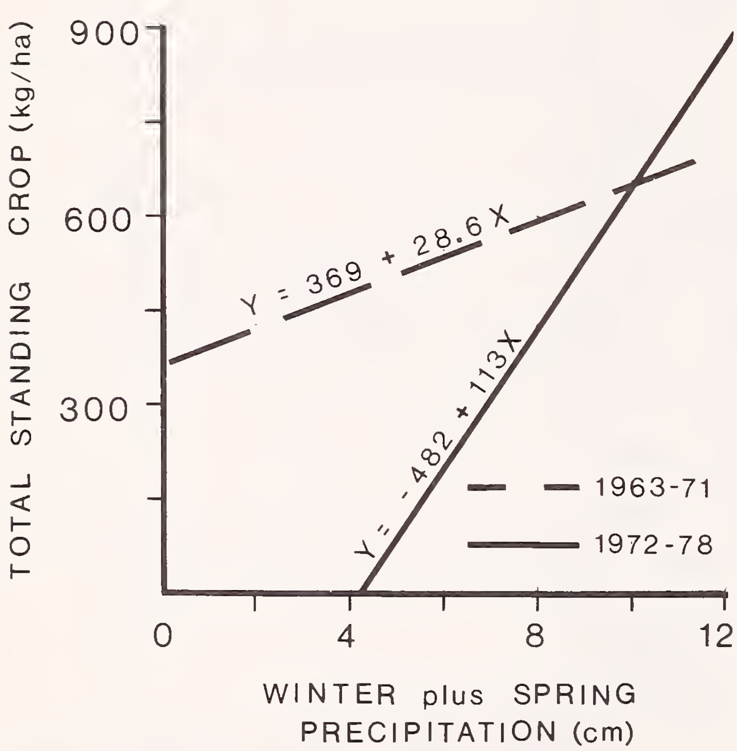

Figure 11.--Regression lines during and after vegetation composition changes at halogeton exclosure 2. The line for 1963-71 represents inefficient water use by the predominantly Gardner saltbush vegetation. The much more efficient water use of the mixed grass-shrub complex during the latter years is exhibited by the steeper regression line.

The two plant groups (grasses and forbs, and shrubs), were not significantly correlated with any season of precipitation during the first period (1963 through 1971), indicating that plant competition dominated intracommunity dynamics. This contrasted with the significant correlations in the analysis of the entire time period. Total standing crop, on the other hand, was significantly correlated with winter plus spring precipitation during this first period.

By 1971, the exclosures had been protected from grazing for 16 years, and the community dynamics during the 1972 to 1978 period appeared to be changing less than in the early period of 1963 to 1971. When the community shifts slowed down in this second period, the individual plant groups were significantly correlated with a period or periods of seasonal precipitation in the same manner as the results of the entire time period (table 3). Total standing crop was also significantly correlated with winter plus spring precipitation during the later period. Precipitation was once again the dominating influence on the plant community.

When the regressions for total standing crop in each period were compared, the total standing crop increase per unit of spring moisture was much less responsive during the early period than during the later period (fig. 10). The very steep regression slope for the later period suggests a greater water use efficiency of mixed herbaceous and shrubby vegetation as compared to that of the predominately shrubby vegetation during the earlier period. Grass and forb standing crop prior to 1972 comprised 25 percent of the total average standing crop. From 1972 through 1978, this value attained a seven year mean of 50 percent of the total standing crop. The slopes of the lines shown in figure 10 are significantly different.

The results of these regression analyses indicate that changing community dynamics, exhibited by condition class improvement increase of the present data, can significantly affect the relationship between precipitation and standing crop. Regression analyses of long-term vegetation data have been continually fraught with large variability. A careful analysis of this variability could lead to a more significant understanding of the vegetation-precipitation relationship.

SUMMARY

The Big Horn Basin is a vast semi-arid part of north-central Wyoming. Although vegetation and climate are similar to comparable areas of Idaho and Utah, west of the Continental Divide, important differences exist in temperature and moisture characteristics, including delayed initiation but accelerated spring warmup, and moisture concentrated during the growing season.

Funding and research to combat invasion by halogeton were initiated in the mid-1950's. In addition to the establishment of livestock-proof exclosures throughout western Wyoming, the Dry Creek Grazing Intensity Study was initiated in 1956 to determine Gardner saltbush response to different intensities of winter utilization by sheep and to determine the related invasion potential of halogeton. By 1967 it was evident that a winter utilization rate of 35 percent of annual herbage production was acceptable and actually desired in order to stimulate plant and root growth. Halogeton abundance was very specifically disturbance and grazing intensity related. By the late 1960's when improved condition class of the grazing unit vegetation became evident, there was also a comparable halogeton reduction. Where intensive livestock disturbance continued, halogeton abundance was maintained.

The primary analytic intent of this paper was the identification and evaluation of long-term herbage production response to precipitation dynamics in conjunction with long-term protection from the stress of livestock grazing.

The exclosures were constructed on sites where the plant community appeared to have had many years of continuous overuse. Almost total elimination of perennial grasses and forbs had occurred and reduced vigor of Gardner saltbush was evident. Vegetation, from 1955 through 1971, exhibited population changes suggestive primarily of recovery from many years of continuous overuse. During this period grass and forb production was minimal, but increasing.

Data from 1972 through 1978, however, portrayed increasing grass and forb production with corresponding decreasing shrub production. In 1978, after 23 years of protection, grass contributed nearly 50 percent of the standing crop. In contrast, it contributed less than 1 percent after 7 years of protection in 1963.

The results of this study have shown that the vegetation composition of three saltbush exclosures changed significantly under protection from grazing. Additionally, these changes occurred during a time when seasonal precipitation was also changing. Spring precipitation was decreasing and winter precipitation increasing. Analyses of the relationship between precipitation and standing crop, based on the entire period, would have been misleading. It was demonstrated that the changing plant composition affected the relationship of total standing crop to precipitation. During the earlier period, while total herbage production was primarily from saltbush, response to moisture in terms of lb/acre for inch (kg/ha for 1 cm) of precipitation was minimal. During the later period, however, with recovery from historical overuse essentially complete, and herbaceous species contributing as much as one half or more of the total vegetation production, response to precipitation was much more dynamic.

Protection from grazing was only partially responsible for the vegetation trends. The shift of seasonal precipitation, from predominance during spring to greater abundance during winter, became more important through time. Interpretation of climatic-vegetation relations based principally on early short-term records, would have suggested a misleading response to nongrazing. The longer term records, however, provided the opportunity to isolate early responses as recovery from historical overuse. In addition, the total data set afforded comprehensive study of vegetation changes as well as greater definitive capability for prediction of climatic/management interrelationships.

PUBLICATIONS CITED

Bindschadler, H. Native vegetation in relation to soils in parts of Wyoming. Wyo. Range Manage. 3(1): 1-3; 1948.

Blaisdell, J. P. Seasonal development and yield of native plants on the Upper Snake River Plains and their relationship to certain climatic factors. Tech. Bull. 1190. Washington, D.C.: U.S. Department of Agriculture; 1958. 68 p.

Bohmont, D. W.; Beetle, A. A.; Rauchfuss, F. L. Halogeton - what should we do about it? Circ. 48. Laramie, WY: Wyoming Agriculture Experiment Station; 1955. 8 p.

Bruner, A. D.; Robertson, J. H. Halogeton - concern to cattleman. J. Range Manage. 16(6): 312-314; 1963.

Cook, C. W.; Stoddard, L. A. Bull. 364. The halogeton problem in Utah. Logan, UT: Utah Agriculture Experiment Station; 1953. 24 p.

Craddock, G. W.; Forsling, C. L. The influence of climate and grazing on spring-fall sheep range in southern Idaho. Tech. Bull. 600. Washington, D.C.: U.S. Department of Agriculture; 1938. 42 p.

Duhig, J. L. Woodruff built first cabin in Big Horn Basin. Thermopolis, WY: Thermopolis Independent Record, August 26, 1948.

Daubenmire, R. Plant communities: a textbook of plant synecology. New York: Harper and Row; 1968. 300 p.

Erickson, L. C.; Tisdale, E. W.; Morton, H. L.; Zappettini, G. Halogeton - intermountain range menace. Circ. 117. Moscow, ID: Idaho Agriculture Experiment Station; 1951. 3 p.

Fisser, H. G.; Hamner, R. W. Winter sheep grazing study on saltbush range (Greybull), Section I. In: Halogeton research-aridland studies of grazing treatments, ecology, shrub improvement and control, and moisture relationships. Laramie, WY: Wyoming Agriculture Experiment Station; 1963. 8 p. Mimeo.

Fisser, H. G.; Owens, M. K.; Uhlich, J. W.; Waugh, W. J.; Rodgers, D. R.; Hargis, N. E. Exclosure production, cover and precipitation studies. In: Phenology and production studies on semi-arid shrub types. Vol. II. Sci. Rep. 1106. Laramie, WY: Wyoming Agriculture Experiment Station; 1980. 61-216.

Fisser, H. G.; Robinson, L. R.; Kirkham, D. R.; Steger, R.; Noller, G. Winter sheep grazing study on saltbush range (Greybull). Section I. In: Halogeton treatments, ecology, shrub improvement and control, and moisture relationships. Laramie, WY: Wyoming Agriculture Experiment Station; 1966. 11 p. Mimeo.

Fisser, H. G.; Steger, R. E. Winter sheep grazing study on saltbush rangeland. Sci. Rep. 36. Laramie, WY: Wyoming Agriculture Experiment Station; 1967. 9 p.

Fisser, H. G.; Trueblood, D. C.; Samuelson, D. D. Soil/vegetation relationships on rangeland exclosures in the Grass Creek Planning Unit of North Central Wyoming. Sci. Rep. 969. Laramie, WY: Wyoming Agriculture Experiment Station; 1979. 279 p.

Fisser, H. G.; Wight, J. R. Winter sheep grazing study on saltbush range (Greybull). In: Halogeton research - arid land studies of grazing treatments, ecology, shrub improvement and control, and moisture relationships. Laramie, WY: Wyoming Agriculture Experiment Station; 1965. 85 p. Mimeo.

Frink, M. Cow country cavalcade. Denver, CO: Old West Publishing Co.; 1954. 243 p.

Frischknecht, N. L. How far will halogeton spread? J. Soil and Water Conservation 22(4): 135-139; 1967.

Hastings, J. R.; Turner, R. M. The changing mile: an ecological study of vegetation change with time in the lower mile of an arid and semiarid region. Tucson, AZ: University of Arizona Press; 1965. 317 p.

James, L. F.; Cronin, E. H. Management practices to minimize death losses of sheep grazing halogeton infested range. J. Range Manage. 27(6): 424-432; 1974.

Joyce, L. A. Climate/vegetation relationships in the northern Great Plains and the Wyoming north-central Basins. Fort Collins, CO: Colorado State University; 1981. 373 p. Dissertation.

King, N. J. Hydrologic data Wind River and Fifteen-mile Creek Basins, Wyoming, 1947-54. Water Supply Paper 1475-A. Washington, D.C.: U.S. Department of Interior, Geol. Survey; 1959. 44 p.

Lewis, J. K.; Gartner, F. R.; Embry, L. B.; Nesvold, John. The effect of level of winter supplementation and intensity of summer grazing on steer gains on native range. In: Research progress report. Circ. 171. Brookings, SD: South Dakota Agriculture Experiment Station; 1965. 29-43 p.

Morton, H. L.; Haas, R. H.; Erickson, L. C. Halogeton and its control. Bull. 307. Moscow, ID: Idaho Agriculture Experiment Station; 1959. 24 p.

Palmer, E. J. Can we control halogeton? Our Public Lands. 5(1): 4, 5, 18, 19, 22, 23; 1955.

Rauchfuss, F. L.; Bohmont, D. W.; Beetle, A. A. Halogeton - how to live with it. Circ. 48 (rev.). Laramie, WY: Wyoming Agriculture Experiment Station; 1957. 6 p.

Reed, M.; Peterson, R. A. Vegetation, soil, and cattle responses to grazing on Northern Great Plains range. Tech. Bull. 1252. Washington, D.C.: U.S. Department of Agriculture; 1961. 79 p.

Sharp, L. A. Evaluation of the loop procedure of the 3-step method in the salt desert type of southern Idaho. J. Range Manage. 7(2): 83-88; 1954.

Shrader, John A. Wyoming Rangeland Resources. Sci. Rep. 854. Laramie, WY: Wyoming Agriculture Experiment Station; 1978. 87 p.

Smoliak, S. Influence of climatic conditions on forage production on shortgrass rangeland. J. Range Manage. 9(2): 89-91; 1956.

Soil Conservation Service. Location map, technical range site descriptions, Wyoming. M 7-E-18358-L. Portland, OR: U.S. Department of Agriculture, Soil Conservation Service; 1966. 1 p.

Vosler, L. C. An autecological study of Atriplex muttallii in the Big Horn Basin of Wyoming. Laramie, WY: University of Wyoming; 1962. 43 p. Thesis.

Webb, Warren; Szarek, W.; Lauenroth, W.; Smith, M. Primary productivity and water use in native forest, grassland, and desert ecosystems. Ecology 59(6): 1239-47; 1978.

Wight, J. R.; Hanks, R. J. Predicting range herbage production with a water-balance, climate model. J. Range Manage. 34(4): 307-311; 1981.

In: Tiedemann, Arthur R.; McArthur, E. Durant; Stutz, Howard C.; Stevens, Richard; Johnson, Kendall L., compilers. Proceedings--symposium on the biology of Atriplex and related chenopods; 1983 May 2-6; Provo, UT. General Technical Report INT-172. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 309 p.

MOISTURE STRESS, *ATRIPLEX* SPECIES, AND RECLAMATION AT BLACK MESA, ARIZONA

Scott D. Wilkins and Jeffrey M. Klopatek

ABSTRACT: The capacity of native shrubs to withstand extremely negative soil water potentials influences their ability to successfully colonize disturbed sites in the arid Southwest. Plant water potential measurements of *Atriplex canescens* growing on natural areas and reclaimed mine sites were compared to determine seasonal and diurnal patterns of moisture stress and internal water potential components. Soils on reclaimed sites were high in clay and significantly higher in electrical conductivity. *A. canescens* from natural sites had the greatest drought-resistance capacity.

INTRODUCTION

The increasing development of coal reserves in the Intermountain West has focused attention on the unique reclamation difficulties associated with arid lands. Under optimum conditions, normal secondary succession processes in the Four Corners area of Arizona can require from 30 to 50 years or longer before the ecosystem approaches a climax stage (Cook 1976). Seed germination and plant establishment in arid lands are often hindered by insufficient moisture availability during critical times of plant growth and development (Hodder 1977). This is due to unpredictable precipitation patterns, seasonal droughts, extreme temperature variability (seasonally and diurnally), and scanty vegetative cover. Moisture stress problems are further compounded by the altered site conditions brought on by mining and reclamation activities and the physical and chemical characteristics of the mining overburden itself.

Water availability can be restricted by increased runoff and evaporation due to the lack of established vegetative cover, "piping" (rapid percolation to depths beyond the root zone; Dixon 1982), and compaction by massive land-moving, surface-mining equipment (Hodder 1977). Indorante and others (1981) reported that, in comparison with undisturbed soils, newly constructed soils had high bulk densities, moderately fine texture, and lacked structure, resulting in compaction and poor aeration. Spoil material also tended to have higher pH, electrical conductivity (indicating increased salinity), and exchangeable sodium (Indorante and others 1981), characteristics that may result in less available soil moisture (Scholl 1982). Rai and others (1974) found that San Juan, N. Mex., shale mine spoils weathered rapidly to form a thin, fine-textured surface layer which considerably slowed down the reclamation process.

These findings stress the need for research that examines the adaptability of vegetative species that can withstand inhospitable conditions. The research presented in this paper analyzes the drought-resistance potential and adaptability of *Atriplex canescens* and other native shrubs by examining their moisture stress patterns on natural and disturbed sites.

STUDY SITES

The study sites were located at Black Mesa on the Hopi and Navajo Indian Reservations in northeastern Arizona. The mines are operated by the Peabody Coal Company. Black Mesa is a large (ca. 2,100,000-acre; 850 000-ha), heavily dissected highland with locally prominent mesas, canyons, and alluvial plains. The coal seams lie at the base of the Fruitland formation of late Cretaceous age (Packer and Aldon 1978). Soils are generally extensively eroded, poorly developed, and very low in organic matter (Thames and Verma 1975). Elevation ranges between 6,800- and 7,500-feet (2 100- and 2 300-m). Annual precipitation is unpredictable and seasonally distributed, averaging approximately 10- to 12-inches (25- to 30-cm). The precipitation pattern is bimodal, characterized by intense late summer (July to September) convectional thunderstorms and less frequent winter frontal systems. The temperature ranges annually from -15° F to 100° F (-27° C to 38° C).

A total of six sites were examined -- three natural and three reclaimed. Prior to mining

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activities, the reclaimed areas supported vegetation similar to the surrounding natural areas. Following reclamation, the disturbed areas were seeded with various native and nonnative grasses. The reclaimed sites differ in their edaphic characteristics. One is pre-Law (Surface Mining Control and Reclamation Act, 1977) with no topsoil. Two are post-Law; one of these has an extra layer of topsoil (to a depth of 10- to 12-inches; 20- to 25-cm).

The natural areas are characterized as Great Basin conifer woodland, interspersed with a mosaic of Great Basin desertscrub communities (Brown 1982). The uplands are dominated by pinyon-juniper woodland (*Pinus edulis* Engelm. - *Juniperus osteosperma* [Torr.] Little). Valleys and lowlands are dominated by scattered communities of rabbitbrush-snakeweed (*Chrysothamnus* spp. - *Gutierrezia sarothrae* [Pursh.] Britt. & Rusby), big sagebrush (*Artemisia tridentata* Nutt.), shadscale (*Atriplex confertifolia* [Torr. & Frem.] Wats.), fourwing saltbush (*Atriplex canescens* [Pursh.] Nutt.), and greasewood (*Sarcobatus vermiculatus* [Hook.] Torr.). Native grasses include galleta (*Hilaria jamesii* [Torr.] Benth.), blue grama (*Bouteloua gracilis* [H.B.K.] Lag.), Indian rice grass (*Oryzopsis hymenoides* [R. & S.] Ricker), and bottlebrush squirreltail (*Sitanion hystrix* [Nutt.] J.G. Sm.).

The predominant vegetation on the reclaimed sites consists of nonnative grasses, chiefly crested wheatgrass (*Agropyron desertorum* [Fisch.] Schult.), western wheatgrass (*Agropyron smithii* Rydb.), and smooth brome (*Bromus inermis* Leyss.), with scattered occurrences of fourwing saltbush, Russian thistle (*Salsola kali* L.), and *Kochia* species.

MATERIALS AND METHODS

Coleman soil moisture and temperature probes were buried at depths of 2-, 8-, and 20-inches (5-, 20-, and 50-cm) at three random locations on each of the six study sites. Soil temperature and resistance readings were measured using a combination soil moisture and temperature meter (Soil Test Model 300A). Concurrent air temperature and relative humidity readings were measured (using a sling-psychrometer) to correlate plant moisture stress with the vapor-pressure deficit of the atmosphere. Soil samples were taken from each site and analyzed for physical and chemical characteristics, including soil texture (Bouyoucos hydrometer method; Bouyoucos 1936), pH (with 0.01 M $CaCl_2$ solutions 1:1), electrical conductivity, and saturation percentage (U.S. Salinity Lab 1954; Black 1965).

Plant water potential measurements were taken in the field with a Scholander-type portable pressure chamber using nitrogen gas (Scholander and others 1965, 1966; Boyer 1967a; Waring and Cleary 1967; Tyree and Hammel 1972; Cline and Campbell 1976). Measurements were taken immediately preceding dawn to compare plants following the period of greatest soil moisture recharge and, therefore, the time of least plant moisture stress (Scholander 1966; Waring and Cleary 1967; Halvorson and Patten 1974; Branson and Shown 1975). Additionally, measurements were taken seasonally (September, January, March, and July) over 24-hour periods on both natural and reclaimed sites to compare the seasonal and diurnal patterns of plant moisture stress.

Water potential components were calculated using pressure-volume curves (Scholander and others 1965; Scholander 1966; Hellkvist and others 1974; Cheung 1975; Ladiges 1975; Hinckley and others 1980; Monson and Smith 1982). Excised fourwing saltbush (*A. canescens*) stems were immediately (<10-sec) placed under water, recut within 2-inches (5-cm) of the excised end, enclosed in a plastic bag, and allowed to reach full saturation (12- to 15-hours) (Scholander 1966; Boyer 1967b; Hellkvist and others 1974; Monson and Smith 1982; Hensen and others 1983). A modified pressure chamber was employed to allow the simultaneous testing of four stems of each species (Monson and Smith 1982). Four plants were placed in the pressure chamber with the cut ends slightly protruding. A Pasteur pipette filled with dry tissue paper was then placed over each stem to collect the liquid expressed at each pressure increment. Each pipette was weighed to within 3.53×10^{-6}-oz (0.1-mg) before and after each collection on an analytical balance (Mettler). Using the method outlined by Monson and Smith (1982), the pressure was progressively increased in 6.9-bar (0.69-MPa) increments to a maximum of 62.1-bars (6.21-MPa), each pressure acting as the balancing pressure of Scholander's method. The total volume of liquid expressed (V_e) from each sample was then added to the total sample fresh mass immediately following the analysis to obtain the original sample fresh mass (FM). Dry mass (DM) was determined after ovendrying for 48-hours at 221° F (105° C). The relative water content (RWC) was calculated from:

$$RWC = (FM - DM) - V_e / (FM - DM).$$

The internal water potential components were determined by extrapolation from pressure-volume curves using the equation (Tyree and Richter 1981; Monson and Smith 1982):

$$1/P = (V_o - V_e) / [RTN_s - F(V)],$$

where P = equilibrium balance point;

V_o = symplastic water volume at full hydration;

V_e = volume of liquid expressed at that pressure;

R = universal gas constant;
T = Kelvin temperature;
N_s = total solute concentration in all cells;
$F(V)$ = relation of turgor pressure to the volume of liquid remaining in all cells.

As V_e increases, $1/P$ decreases curvilinearly to the point of plasmolysis, due to decreases in the turgor pressure. Beyond plasmolysis (TLP = turgor loss point), turgor pressure drops to 0 and the relationship between $1/P$ and $(V_o - V_e)$ (the symplastic water volume) becomes linear, dependent only on changes in the osmotic potential. When this linear relationship is extrapolated back to the ordinate, it gives an estimate of the initial osmotic potential of the plant at full turgor. Additionally, turgor pressure can be estimated by subtracting the osmotic potential from the total plant water potential (Scholander 1966; Boyer 1967a, 1967b; Hellkvist and others 1974; Monson and Smith 1982).

RESULTS AND DISCUSSION

Soils

Comparisons of soil characteristics between the reclaimed and natural sites reveal no significant differences for pH or saturation percentage (Duncan's Multiple Range Test; table 1). However, the mean electrical conductivity measure (EC) was significantly higher ($p<0.01$) in the reclaimed sites than in the natural sites. This was especially evident at the 8- and 20-inch (20- and 50-cm) depths. Highest electrical conductivity was measured at the 20-inch (50-cm) depth at all sites, natural and disturbed, except for the post-Law reclaimed site. Since high soil solute levels significantly decrease soil water potential and increase plant water stress (Walter and Stadelmann 1974; Etherington 1982), this factor may substantially hinder plant establishment and revegetation efforts. It is important to note that the highest EC measurements on the reclaimed sites occurred below the topsoil layer (ca. 4- to 8-inches; 10- to 20-cm) in the overburden material. This would tend to emphasize the importance of topsoiling/topdressing reclaimed mine spoils at Black Mesa to increase the probability of revegetation success.

Table 1.--Selected soil parameters for the three reclaimed and three natural sites.[1]

Site	Depth	Sand	Silt	Clay	pH	EC[2]	Sat[3]
	in	percent				mmhos	%
Pre-Law	2	62.2	21.4	16.4	7.75	1.45	34.8
	8	69.6	16.0	14.4	7.70	1.10	32.9
	20	65.6	19.0	15.4	7.87	4.17	34.6
Post-Law	2	65.2	23.0	11.8	7.95	0.56	36.5
	8	56.2	17.0	16.8	7.90	2.12	43.5
	20	54.5	23.8	21.7	7.87	1.85	43.3
Extra topsoil	2	71.6	14.4	14.0	8.20	1.02	28.5
	8	78.6	11.0	10.4	8.25	2.49	27.6
	20	71.6	17.0	11.4	7.72	4.40	34.3
Saltbush	2	52.2	31.8	16.0	7.90	0.73	33.2
	8	37.0	38.6	24.4	7.85	.51	36.7
	20	53.6	31.4	15.0	7.87	1.06	37.0
Pinyon/juniper woodland	2	71.0	19.0	10.0	7.70	0.54	36.8
	8	69.0	16.0	15.0	7.80	.61	36.9
	20	48.0	24.0	28.0	8.00	.97	53.9
Rabbitbrush-snakeweed	2	77.0	20.0	3.0	7.60	0.43	34.1
	8	76.0	20.0	4.0	7.80	.44	37.1
	20	80.2	17.0	2.8	8.00	1.50	46.1

[1]Klopatek, J. M. Unpublished data on file at Tempe, AZ: Arizona State University, Department of Botany and Microbiology; 1983.

[2]Electrical conductivity.

[3]Saturation percentage = wt. water/soil dry wt.

These data appear to contradict other studies conducted at Black Mesa that report no differences in physical or chemical characteristics between the overburden and the undisturbed soils (Verma and Thames 1978). Suitable topsoil dressing (as defined by reclamation laws; Power 1978) is often taken from drainages on the specific mine cut. Several investigators have reported such alluvial deposits to be high in salt content (Branson and Shown 1975; Hodder 1977). This factor may increase salinity in the reclaimed topsoil and be important in limiting soil moisture uptake by plants during periods of reduced water availability (Louderbough and Potter 1982).

Atriplex canescens has been shown to be a halophyte, tolerating high salt conditions (Osmond and others 1980), and to have increased root and shoot growth in slightly saline conditions, compared to nonsaline conditions (Al-Jiburi 1972). Saltbush and other halophytic cold desert shrubs may be excellent colonizers of newly disturbed areas because of their ability to tolerate physiological water stress due to either dry or saline soil conditions. However, Al-Jiburi (1972) also noted that root and shoot growth of *A. canescens* was inversely related to the electrical conductivity of the soil solution above a certain threshold. Decrease in growth was noted at <7 mmhos. Since reclaimed soils have EC levels approaching this range, establishment of saltbush and other less salt-tolerant native species may be adversely affected.

Soils in the rabbitbrush-snakeweed community (table 1) show a significantly lower ($p<0.01$) percentage of clay in all horizons than any other community. This site was the driest, with very shallow soils containing a high percentage of rock. The low clay and high sand content may be important factors causing the soils to have a low moisture-holding capacity and increasing the moisture stress of plants growing on this site. The saltbush community, growing in a deep alluvial plain, shows significantly less sand than any other site.

Although not statistically significant, there seems to be a trend toward increasing pH and salinity with increasing depth in both the natural and reclaimed sites. The reclaimed site treated with an additional layer of topsoil has more sand, less silt and clay, lower saturation percentage, and higher pH and EC than the reclaimed sites with less topsoil. The high clay content found in all soils except the rabbitbrush community decreases the soil moisture potential.

Soil moisture resistance measurements indicate that, during periods of adequate precipitation, reclaimed soils have a higher relative water content than undisturbed soils, with two exceptions. During the winter when temperatures dropped below 14° to 19° F (-7° to -10° C) nightly, the natural sites contained more water. More important, the saltbush community soils contained more water than the extra-topsoil site at the 20-inch (50-cm) depth from August-December 1982. However, the pattern reversed from January-August 1983, with the saltbush soils becoming drier. On a total volume basis, the post-Law site (4- to 5-inches; 10-cm topsoil) contained the most moisture of the reclaimed soils, followed by the pre-Law site. The extra-topsoil site was the driest, especially at the 8- and 20-inch (20- and 50-cm) depths. There was no significant difference between the post-Law and the extra-topsoil sites at the 2-inch (5-cm) depth. The pre-Law (no topsoil) site was the wettest at this depth (containing the highest percentage of clay in the upper horizon of all reclaimed sites).

The saltbush community was the driest of the natural sites until the late summer (July) precipitation cycle began. However, it should be noted that these soil moisture comparisons were made during a period of above normal precipitation. During more typical seasonal droughts, the moisture-holding capacities or patterns of these soils may differ markedly. Additionally, some differences in soil moisture levels may be due to water use differences between the grass cover on the reclaimed sites and the shrub cover on the natural sites, or to the utilization of soil water in different horizons because of different rooting depths.

Plant Water Potential

Total plant water potential can be used as an estimate of the realistic soil moisture potential that the plant is experiencing in the rhizosphere and the accompanying internal water stress of the plant (Waring and Cleary 1967). Typically, internal water stress peaks at midday, stabilizes by midnight, and reaches a low before sunrise (Love and West 1972), allowing the plant to relieve its water deficit overnight. The data in table 2 allow a comparison of the mean predawn water potentials of Atriplex canescens on the five study sites during August 1982-March 1983 and April-August 1983. Water potential values correlate strongly both by study site and by area ($F = 13.62$, Spearman Rank Correlation Test). The most negative values are found in the saltbush community that exhibited the high EC readings.

Table 2.--Correlations of mean predawn water potentials of Atriplex canescens by study site and area using Spearmans' Rank Correlation; test for significance by Duncan's Multiple Range Test.

Area	Study site	Aug. 1982-Mar. 1983		Apr. 1983 Aug. 1983	
Natural	Saltbush	[1]32.6	a	[2]20.0	b
	Rabbitbrush	29.3	a	19.1	b
Reclaimed	Extra topsoil	20.0	b	17.6	b
	Pre-Law	15.1	b	15.2	b
	Post-Law	15.0	b	13.1	b
	Natural	30.9	x	19.6	y
	Reclaimed	16.7	y	15.3	y
	($p < 0.01$, $F = 13.62$, $n = 345$)				

[1]All means given in -bars; 1 bar = 0.10 MPa.

[2]Means followed by the same letter are not significantly different at 0.01 probability level.

Seasonally averaged plant water potential readings measured at the natural areas were significantly more negative ($p<0.01$) than at the reclaimed areas, especially during the period of August 1982 through March 1983. This indicates that less soil moisture was available to plants growing on the natural sites through most of the year, thus increasing the level of plant moisture stress. No significant difference is seen between natural and reclaimed sites for the drier period of April-August 1983.

Monthly minimum and maximum stress values of plants growing on the extra-topsoil site and in the saltbush community are compared in table 3. Values are significantly different between sites at each date. Both minimum and maximum measurements demonstrate significantly higher water stress for plants growing on the natural site from August 1982 until May 1983 (table 3). During the critical

Table 3.--Comparison of seasonal predawn minimum and midday maximum water potential values[1] for Atriplex canescens at one natural and one reclaimed site using Duncan's Multiple Range Test. All means followed by the same letter are not significantly different (p<.01).

Time of day	Date	Saltbush community	Extra topsoil
	8/21/82	[2]26.0 a	18.4 b f
	1/07/83	30.8 c	27.3 a
Predawn	5/30/83	7.1 d	12.5 e
maxima	6/18/83	13.5 e	17.1 b
	7/04/83	26.0 a	19.2 b f
	8/27/83	34.0 c j	21.5 f
	1/07/83	46.4 g	33.7 c j
Midday	5/30/83	26.1 a	31.7 c
minima	7/04/83	46.4 g	39.5 h
	8/27/83	50.4 i	35.7 j

[1]Each value represents mean of 8-11 observations.

[2]All means given in -bars; 1 bar = 0.1 MPa.

period from April through June, the soil on the reclaimed site dried out more quickly, causing plants to exhibit more water stress than those of the undisturbed site. This reversal is shown graphically in figure 1, which compares a natural and reclaimed site in May and July. These data appear to contradict the data for the same period in table 2. However, by seasonally averaging the predawn water potential over the entire period (April-August), it only appears that there was always less moisture available in the undisturbed area. When a monthly check of water potential values is examined (table 3), it is apparent that the actual trend is hidden. This trend is demonstrated

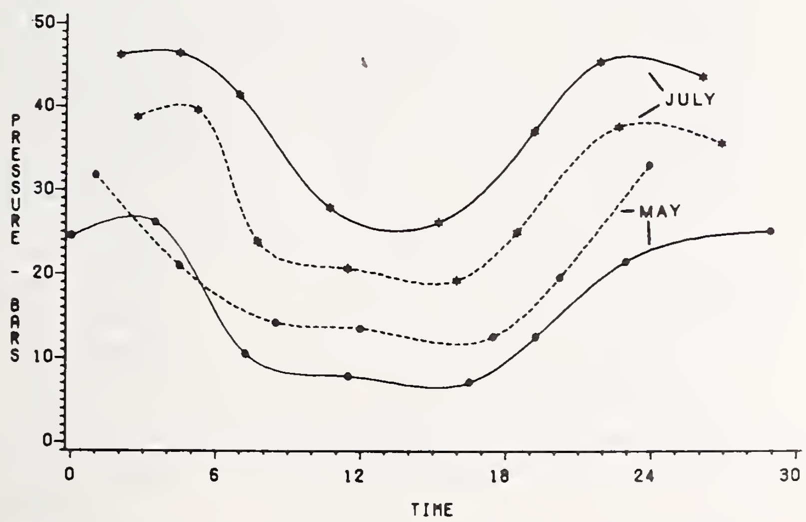

Figure 1.--Comparison of diurnal pattern of plant water potentials at natural and reclaimed sites in May and July 1983. ——— = natural site; -------- = reclaimed site. 1 bar = 0.1 MPa.

by the decrease (becoming more negative) in both the predawn maxima and the midday minima values measured at the reclaimed site. During summer drought, the relationship between the vegetation and the moisture gradient can best be shown by comparing the minimum (most negative) internal water stress at midday rather than the maximum (predawn) (Waring and Cleary 1967; Halvorson and Patten 1974; Syvertsen and others 1975).

The mean difference between daily minima and maxima water potential values for all seasons was 23.5-bars for the natural site and 17.6-bars for the reclaimed site. This difference dropped to 18.8-bars and 19.7-bars respectively during spring and early summer 1983. Although the differences were no longer significant, there was a reversal of pattern. The reclaimed site showed a slightly greater difference between the diurnal maxima and minima. Halvorson and Patten (1974) found that diurnal water potential fluctuation increased with decreasing soil moisture availability. The greatest fluctuation on both sites occurred during periods of the greatest moisture stress, either during the driest period or during the cold winter when water availability was limited by low temperatures.

The seasonal range of maximum and minimum water potential values varied from -6.4-bars to -67.2-bars at the natural site and from -12.5-bars to -39.5-bars at the disturbed site. However, both extremes at the natural site were influenced by climatic anomalies: the -6.4-bar maximum was measured during a September rainfall, and the -67.2-bar minimum during 5° F (-15° C) temperatures in early spring. Removing these two anomalous situations from consideration, the range on the natural site was -7.1-bars to -50.4-bars (table 3). As the summer monsoon season commenced in July, but with below normal precipitation, the reclaimed soils absorbed more moisture and once again the natural soils showed the greatest moisture stress. This pattern may have been influenced by the above normal precipitation during the winter and spring of 1982-83, and the light summer monsoon rainfall of 1983.

Mean predawn water potentials during August 1982 for shrubs in the rabbitbrush community were: A. canescens, -29.3-bars; Artemisia tridentata, -33.5-bars; Chrysothamnus viscidiflorus (Hook.) Nutt., -31.3-bars. Although not significantly different, the A. canescens plants showed slightly higher (less negative) water potential values than the other neighboring shrubs. By comparison, midday values for shrubs growing on the rabbitbrush site in July 1983 were: A. canescens, -39.6-bars; A. confertifolia, -46.1-bars; and Eurotia lanata (Pursh.) Moq., -46.4-bars. The saltbush plants did have significantly higher (p<0.01) water potential

values during this summer drought season, indicating that they were operating under less moisture stress than the other shrubs.

Diurnal patterns of plant moisture stress are compared with the vapor-pressure deficit of the atmosphere (VPD) for A. canescens in the saltbush community in figure 2. During September 1982 there was high soil moisture content, low vapor-pressure deficit, and low plant moisture stress due to heavy seasonal precipitation. Significant correlation was

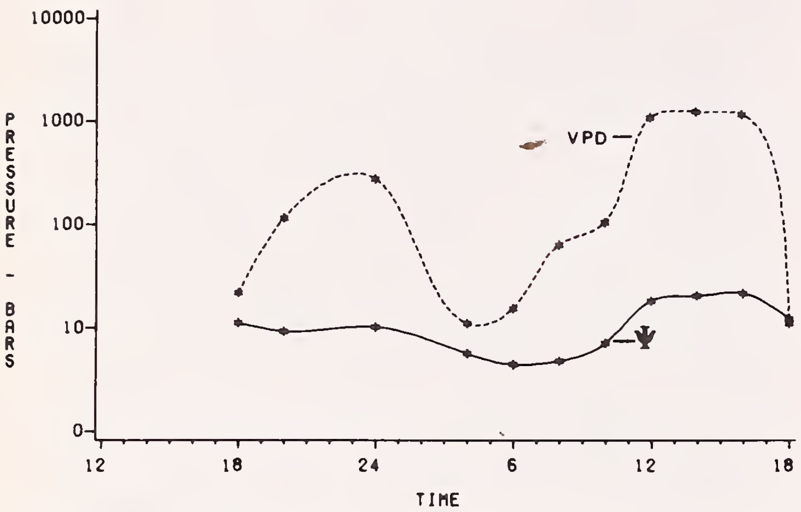

Figure 2.--Comparison of diurnal pattern of moisture stress and atmospheric vapor-pressure deficit for Atriplex canescens at saltbush community on Sept. 4, 1983. 1 bar = 0.1 MPa; VPD = vapor-pressure deficit; Ψ = plant water potential.

found between plant moisture stress and VPD ($F = 63.0$, $r^2 = .87$; Pearson product-moment correlation). Water potential measurements did not increase markedly until 1100 hours when the skies cleared and the vapor-pressure deficit began to rise. In January, cold nocturnal temperatures (<14° F; <-10° C) further depressed the VPD, which rose only during the warm midday hours (1300-1800 hours). Cold temperatures also depressed the typical peak of increasingly more negative plant water potential values that occurs immediately after sunrise with the rapid increase of the VPD and stomatal opening (Klepper 1968).

Plant water potentials were not significantly correlated with VPD during the cold winter months. This was primarily due to low soil water availability caused by extremely low soil temperatures. The high day time temperature difference between the air and soil caused the plants to experience extreme moisture stress. At all other times of the year, plant water potentials and VPD were highly correlated ($r^2 = .70$ to $r^2 = .96$). In all cases, plants under the least moisture stress showed the highest correlation between water potential and VPD.

An anomalous diurnal plant water stress pattern was detected during the cold winter months when the air temperature routinely dropped below 19° to 14° F (-7° to -10° C) and soil temperatures at 2- and 8-inches (5- and 20-cm) dropped below 23° and 32° F (-5° and 0° C) respectively. Unable to efficiently recharge from the soil moisture at night due to the low temperatures, the plant's period of minimum stress came in the early evening immediately following sunset (1800-2000 hours). December 1982 predawn readings went beyond -70-bars (off scale) at both natural sites when the temperature dropped below 5° F (-15° C) (returning to mean maximum -40.7-bars at 1200 hours). This pattern remained constant until March when nocturnal temperatures began to rise above 32° F (0° C). Other anomalous patterns have been reported (Syvertsen and others 1975) due to effects of soil moisture or stomatal closure. Note the rapid rise and immediate decline of the water potential curve at sunrise during March in figure 3 due to the early attainment of stress conditions and possibly subsequent stomatal closure (Cline and Campbell 1978). The stress was intensified by the extremely cold predawn soil and atmospheric temperatures (21° F; -6° C) that prevented easy water movement through the soil-plant-atmosphere continuum.

Water potential measurements from September, January, March, and July are overlaid in figure 3 to display the gradual increase in plant water stress from September 1982 through July 1983. Of particular interest is the close agreement of the afternoon (1200-1800 hours) water potential values at all dates, which contrasts with the widely

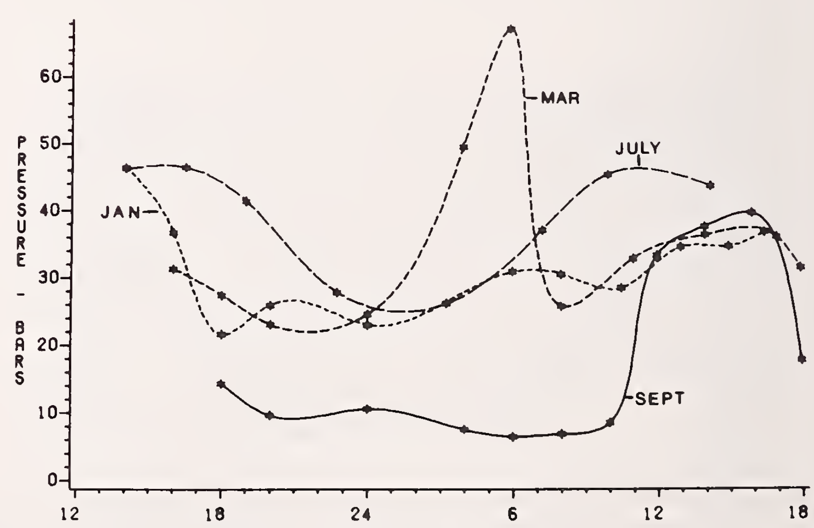

Figure 3.--Seasonal comparison of four moisture stress patterns of Atriplex canescens at saltbush community for September 1982, and January, March, and July 1983. 1 bar = MPa.

disparate values during the remainder of the diurnal cycle. The March peak (most negative potential) appears anomalous in comparison with the other moisture stress patterns and may be due to high water stress during the day and the inability of the plant to recharge sufficiently at night due to low nocturnal atmospheric and soil temperatures that prevent efficient water uptake by the roots.

A high degree of variability in water potential measurements was detected among A. canescens sampled on all sites at all seasons. Differences were not significant between sites, but there was a trend toward greater variability with greater moisture stress or during periods of climatic fluctuation (e.g., precipitation). No significant difference was detected between sites, or between natural and reclaimed areas. Mean variability measured 7-bars, with occasional values to 15-bars.

Stutz (1982) has reported that Atriplex is by far the most variable of all western America chenopods, commonly forming numerous locally adapted ecotypes through rapid gene mutation and introgressive hybridization. The genetically controlled adaptations include variations in root-sprouting capability, tolerance of heavy clay soils, and drought tolerance. It is suggested that much of the plant water potential variability between A. canescens individuals of the same ecotype or site can be explained by this genetic diversity.

Pressure-Volume Curves

Scholander and others (1965) stated that "the pressure-volume curve gives a striking picture of the water stress of a plant and reflects with fair accuracy the turgor of the leaf cells," by delineating a plant's water potential components. A plant's adaptation to drought stress is reflected in its low seasonal water potential components (Monson and Smith 1982). Species in habitats characterized by periods of substantial water stress exhibit relatively low (more negative) internal osmotic potentials with positive turgor pressure. Total plant water potential = osmotic potential + turgor pressure (Cline and Campbell 1976; Roberts and others 1980). The capacity to maintain turgor at low water potentials allows a plant access to both a greater volume of soil water and a longer growing season, and to be physiologically active during periods of low soil water and high atmospheric demand (Monson and Smith 1982).

Pressure-volume curves shown in figure 4 allow a comparison of three shrubs from the rabbitbrush community on August 22, 1982. The data in table 4 compare the osmotic potential at full turgor and the turgor loss

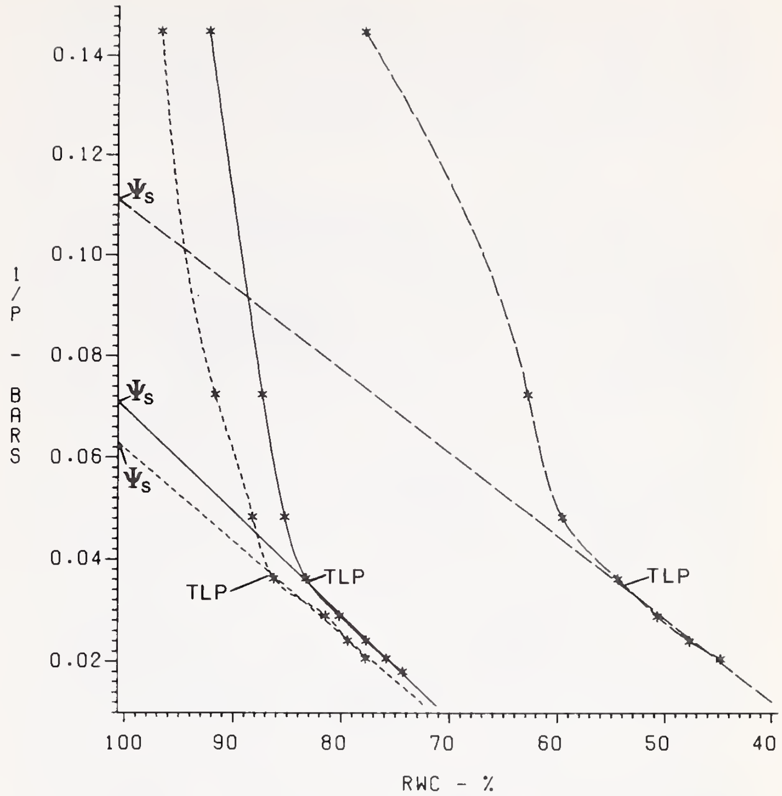

Figure 4.--Pressure-volume curves for three shrub species at rabbitbrush community on Aug. 22, 1982; each curve is the mean of four observations. ——— = Atriplex confertifolia; ········· = Atriplex canescens; — — — = Artemisia tridentata; linear regression line by least squares method. TLP = turgor loss point; Ψ_s = initial osmotic potential at full turgor.

Table 4.--Water potential components obtained from pressure--volume curves for shrub species in the rabbitbrush community. All values are in -bars; each value is the mean of 4 values.

Species	Date	Osmotic potential (full turgor)	Turgor loss pot.
Atriplex canescens		20.7	31.9
Artemisia tridentata	4/14/83	15.2	27.6
Chrysothamnus viscidiflorus		19.8	28.4
Atriplex canescens		16.2	31.9
Artemisia tridentata	8/22/82	9.1	24.9
Atriplex confertifolia		14.3	33.0

potential values obtained from these curves. The osmotic potential at full turgor (or initial osmotic potential) is obtained by calculating the intercept of the linear portion of the pressure-volume curve at 100 percent RWC (relative water content) by least squares regression (Jane and Green 1983). It has been stated that variation in the water potential at the turgor loss point is closely correlated with osmotic potential and could be used to rank species in order of increasing drought adaptability and stress

toleration (Monson and Smith 1982; Jane and Green 1983). Additionally, Hinckley and others (1980) found a close link between the turgor loss point and the turgor potential threshold for stomatal closure.

As seen in table 4, A. canescens had significantly more negative values than Artemisia tridentata on both dates. No significant difference was seen between A. canescens and either Chrysothamnus viscidiflorus or A. confertifolia. Comparison of the shapes of the curves of figure 4 can also be made. A. canescens showed the least decrease in RWC for a given decline in water potential, indicating a greater drought resistance (lower line, steeper angle and slope) (Hinckley and others 1980; Clayton-Greene 1983). Using the osmotic potentials and shape of the curves, the rank of the shrubs in order of decreasing drought resistance potential was: Atriplex confertifolia > Chrysothamnus viscidiflorus > Atriplex canescens > Artemisia tridentata.

The ability of a plant to control or influence its seasonal internal osmotic potential (osmoregulation) is expressed in its total osmotic variation (Monson and Smith 1982; Jane and Green 1983). Increasingly negative osmotic potentials are an adaptive response to lowered soil moisture availability. The lower osmotic potential steepens the water potential gradient from substrate to plant, allowing turgor to be maintained at lower plant water potentials (Roberts and others 1980). Comparison of osmotic measurements of A. canescens from both tables 4 and 5 shows no significant variation in osmotic potential, indicting no great capacity for osmoregulation. In contrast, Artemisia tridentata showed great osmotic variablity between the two dates, indicating that it is an osmoregulator.

Table 5.--Comparison of water potential components for Atriplex canescens from various sites on two dates. All values are in -bars; each value is mean of 4 observations.

Site	Date	Osmotic potential (full turgor)	Turgor loss pot.
Rabbitbrush		13.6	31.3
Saltbush	6/18/83	19.9	33.1
Extra topsoil		16.2	31.4
Saltbush		19.7	38.6
Extra topsoil	7/04/83	17.7	27.9
Pre-Law		17.9	30.0

However, there was a decrease in the turgor loss point (table 5) in A. canescens sampled on June 18 and July 4, 1983, associated with a decrease in soil moisture availability (-33.1- to -38.6-bars). This would allow the plants in the saltbush community to maintain turgor while the soil moisture decreased, and indicates at least some capacity for osmoregulation, despite the slight variation in osmotic potentials.

Comparison of the pressure-volume curves for A. canescens grown on different sites (table 5 and figure 5-6) reveals that plants from the saltbush community had significantly more negative initial osmotic potentials, turgor loss potentials, and steeper slopes to their respective curves than plants from the

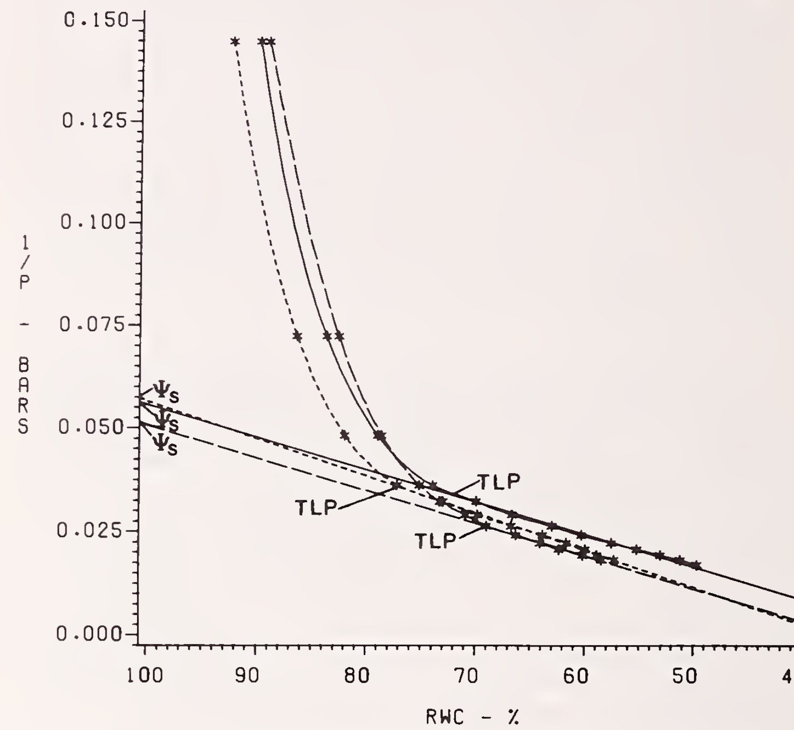

Figure 5.--Pressure-volume curves for Atriplex canescens at three sites on June 18, 1983; each curve is mean of four observations. ——— = rabbitbrush comm.; ------ = extra topsoil; – – – – = saltbush comm.; linear regression line by least squares method. TLP = turgor loss point; Ψ_s = initial osmotic potential at full turgor.

rabbitbrush community, or from either reclaimed site. This indicates that A. canescens plants growing on natural sites have greater drought-resistance potential then those on reclaimed sites. The significant difference between sites is indicated in the slope of the curves shown in figure 5.

CONCLUSIONS

Reclaimed sites on Black Mesa contained more soil water than natural sites from August 1982 to March 1983. But during the period of most extreme moisture stress, April to June 1983, the pattern reversed; the natural soils contained more water. The lack of water in reclaimed soils during this critical season, coupled with high clay content and significantly higher salinity values, produced very negative soil water potentials;

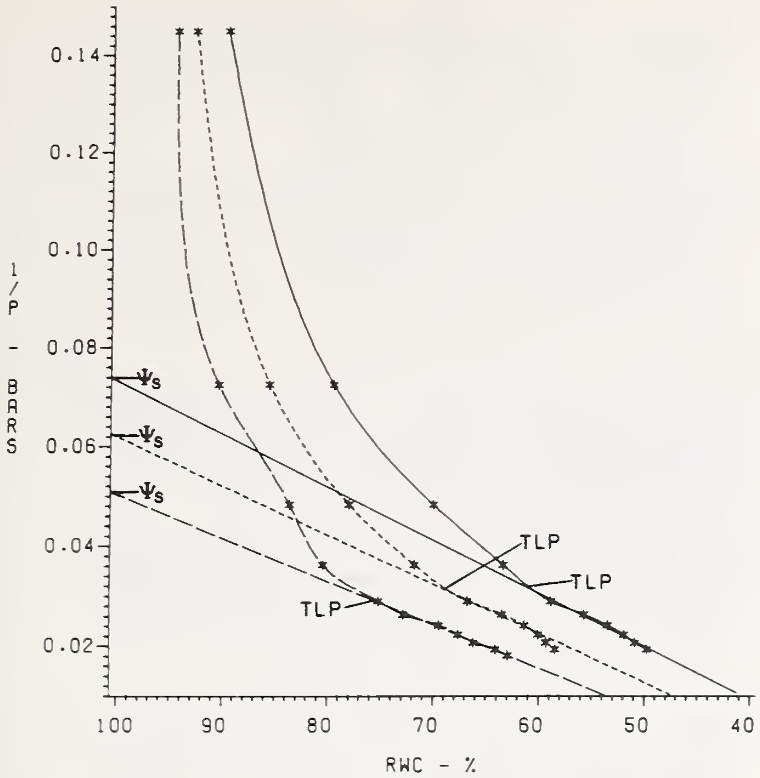

Figure 6.--Pressure-volume curves for Atriplex canescens at three sites on July 4, 1983; each curve is mean of four observations. ——— = post-Law; ------- = extra topsoil; — — — — = saltbush comm.; linear regression line by least squares method. TLP = turgor loss point; Ψ_s = initial osmotic potential at full turgor.

these may have adversely affected plant establishment and mortality. Atiplex canescens appears capable of tolerating high moisture stress through ecotypic adaptation, genetic variability, and physiological drought-resistance capability.

Pressure-volume curves indicate that A. canescens plants from natural sites have lower initial osmotic potentials and maintain positive turgor at lower water potentials than plants from disturbed sites, giving them a greater drought-resistance potential. Pressure-volume curves indicated that A. confertifolia has a greater dought tolerance than Chrysothamnus viscidiflorus, Atriplex canescens or Artemisia tridentata growing on the same site.

The ability of A. canescens to osmoregulate as a means of dealing with increasing moisture stress needs further investigation. More study is also needed on comparing the moisture stress patterns of important members of all major plant communities in the area and determination of their internal water potential components.

The necessity of using native shrubs that can withstand intensive grazing pressures and dessicating conditions for ecosystem stabilization is well documented (Packer 1974; Aldon 1978). Atriplex canescens is one of the most important shrubs for revegetation in the arid Southwest (Plummer 1977), especially in reclaiming mine spoils that have been physically and chemically altered. Internal water potential components may be used to compare drought-resistance capacities of various species, or their degree of moisture stress in various microhabitats. Although A. canescens is well-suited for revegetation activities, its great physiological and morphological variability makes it unacceptable as a reference plant (Klepper 1968; Waring and Cleary 1967; Stutz 1982) to detect differences in soil moisture regimes.

Plant-soil-atmosphere water relations are the key to successful colonization of harsh arid sites. Additional research is being completed to correlate the soil water potential with the total plant water potential and atmospheric vapor pressure deficit on natural and reclaimed sites. This will allow correlation with the actual plant water potential variations taking place. More study on individual plant water potential components and requirements is also indicated to determine the best procedures to follow when revegetating disturbed lands in the arid Southwest.

ACKNOWLEDGEMENTS

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PUBLICATIONS CITED

Al-Jibury, L. K. Salt tolerance of some desert shrubs in relation to their distribution in the southwestern deserts of North America. Tempe, AZ: Arizona State University; 1972. 126 p. Dissertation.

Aldon, E. F. Reclamation of coal-mined land in the Southwest. J. Soil and Water Cons. 33: 75-79; 1978.

Bennert, W. F.; Mooney, H. A. The water relations of some desert plants in Death Valley, California. Flora. 168: 405-427; 1979.

Black, C. A., ed. Methods of soil analysis. Madison, WI: Am. Soc. Agron.; 1965. 1572 p.

Bouyoucos, C. J. Directions for making mechanical analysis of soil by the hydrometer method. Soil Sci. 42: 225-229; 1936.

Boyer, J. S. Leaf water potentials measured with a pressure chamber. Plant Physiol. 42: 133-137; 1967.

Boyer, J. S. Matric potential of leaves. Plant Physiol. 42: 213-217; 1967.

Branson, F. A.; Shown, L. M. Soil moisture stress as related to plant-moisture stress in Big Sagebrush. J. Range Manage. 28: 212-215; 1975.

Brown, D. E., ed. Desert plants: biotic communities of the American Southwest - United States and Mexico; Vol. 4, No. 1-4. Tucson, AZ: University of Arizona; 1982. 342 p.

Cheung, Y. N. S.; Tyree, M. T.; Dainty, J. Water relations parameters on single leaves obtained in a pressure bomb and some ecological interpretations. Can. J. Bot. 53: 1342-1346; 1975.

Clayton-Greene, K. A. The tissue water relationships of Callistris columellaris, Eucalyptus mellidora, and Eucalyptus microcarpa investigated using the pressure-volume technique. Oecologia. 57: 368-373; 1983.

Cline, R. G.; Campbell, G. S. Seasonal and diurnal water relations of selected forest species. Ecology. 57: 367-373; 1976.

Cook, C. W. Reclamation planning. In: Vo[illegible]es, K. C., ed. Reclamation of western surface-mined lands. Fort Collins, CO: Ecology Consultants, Inc.; 1976: 23-24.

Dixon, R. M. Infiltration, runoff, and erosion control through surface management. In: Aldon, E. F.; Oaks, W. R., eds. Reclamation of mined lands in the Southwest: Symposium proceedings; 1982 October 20-22; Albuquerque, NM; Albuquerque, NM: Soil Conservation Society of America; 1982; 91-97.

Etherington, J. R. Environment and plant ecology. New York: John Wiley and Sons; 1982. 497 p.

Halvorson, W. L.; Patten, D. T. Seasonal water potential changes in Sonoran desert shrubs in relation to topography. Ecology. 55: 173-177; 1974.

Hellkvist, J.; Richards, G. P.; Jarvis, P. G. Vertical gradients of water potential and tissue water relations in Sitka spruce trees measured with the pressure chamber. J. Appl. Ecol. 11: 637-667; 1974.

Hensen, I. E.; Alagarswamy, G.; Mahalakshmi, V.; Bidinger, F. R. Stomatal response to water stress and its relationship to bulk leaf water status and osmotic adjustment in Pearl Millet (Pennisetum americanum [L.]Leeke). J. Exp. Bot. 34: 442-450; 1983.

Hinckley, T. M.; Duhme, F.; Hinckley, A. R.; Richter, H. Water relations of drought hardy shrubs: osmotic potential and stomatal reactivity. Plant, Cell, & Environ. 3: 131-140; 1980.

Hodder, R. L. Dry land techniques in the semiarid West. In: Thames, J. L., ed. Reclamation and use of disturbed land in the Southwest. Tucson, AZ: University of Arizona Press; 1977: 217-223.

Indorante, S. J.; Jansen, I. J.; Boast, C. W. Surface mining and reclamation: Initial changes in soil characteristics. J. Soil Water Cons. 36: 347-351; 1981.

Jane, G. T.; Green, T. G. A. Utilisation of pressure-volume techniques and non-linear least squares analysis to investigate site induced stresses in evergreen trees. Oecologia. 57: 380-390; 1983.

Klepper, B. Diurnal pattern of water potential in woody plants. Plant Physiol. 43: 1931-1934; 1968.

Ladiges, P. Y. Some aspects of tissue water relations in three populations of Eucalyptus viminales Labill. New Phytol. 75: 53-62; 1975.

Louderbough, E. T.; Potter, L. D. Mancos shale: Some physical and chemical properties which affect vegetative communities on shale outcrops. In: Surface mining hydrology, sedimentology, and reclamation symposium; 1982 December 5-10; Lexington, KY; Lexington, KY: University of Kentucky; 1982: 547-550.

Love, D. L.; West, N. E. Plant moisture stress patterns in Eurotia lanata and Atriplex confertifolia. Northwest Sci. 46: 44-51; 1972.

Monson, R. K.; Smith, S. D. Seasonal water potential components of Sonoran Desert plants. Ecology. 63: 113-123; 1982.

Osmond, C. B.; Bjorkman, O.; Anderson, D. J. Physiological processes in plant ecology - toward a synthesis with Atriplex. New York: Springer-Verlag; 1980. 468 p.

Packer, P. E. Rehabilitation potentials and limitations of surface-mined land in the Northern Great Plains. Gen. Tech. Rep. INT-14. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1974. 44 p.

Packer, P. E.; Aldon, E. F. Revegetation techniques for dry regions. In: Schaller, F.W.; Sutton, P., eds. Reclamation of drastically disturbed lands symposium: Proceedings; 1976 August 9-12; Ohio Agricultural Research and Experiment Station; Wooster, OH; Madison, WI:

American Society of Agronomy, Crop Science Society of America, Soil Science Society of America; 1978: 425-450.

Plummer, A. P. Revegetation of disturbed Intermountain area sites. In: Thames, J. L., ed. Reclamation and use of disturbed land in the Southwest. Tucson, AZ: University of Arizona Press; 1977: 302-339.

Power, J. F. Reclamaton research on strip-mined lands in dry regions. In: Schaller, F.W.; Sutton, P., eds. Reclamation of drastically disturbed lands symposium: Proceedings; 1976 August 9-12; Ohio Agricultural Research and Experiment Station; Wooster, OH; Madison, WI: American Society of Agronomy, Crop Science Society of America, Soil Science Society of America; 1978: 521-535.

Rai, D.; Wierenga, P. J.; Gould, W. J. Chemical and physical properties of core samples from coal-bearing formation in San Juan County, New Mexico. Res. Rep. 287. Las Cruces, NM: New Mexico State University Agriculture Experiment Station; 1974. 13 p.

Roberts, S. W.; Strain, B. R.; Knoerr, K. R. Seasonal patterns of leaf water relations in four co-occurring forest tree species: Parameters from pressure-volume curves. Oecologia. 46: 330-337; 1980.

Scholander, P. F. The role of solvent pressure in osmotic systems. Proc. Natl. Acad. Sci. 55: 1407-1414; 1966.

Scholander, P. F.; Bradstreet, E. D.; Hammel, H. T.; Hemmingsen, E. A. Sap concentrations in halophytes and some other plants. Plant Physiol. 41: 529-532; 1966.

Scholander, P. F.; Hammel, H. T.; Bradstreet, E. D.; Hemmingsen, E. A. Sap pressure in vascular plants. Science. 148: 339-346; 1965.

choll, D. Properties of coal spoils of the Navajo Mine in northwest New Mexico. In: Aldon, E. F.; Oaks, W. R., eds. Reclamation of mined lands in the Southwest: Symposium proceedings; 1982 October 20-22; Albuquerque, NM; Albuquerque, NM: Soil Conservation Society of America; 1982: 80-86.

Stutz, H. C. Broad gene pools required for disturbed lands. In: Aldon, E. F., Oaks, W. R., eds. Reclamation of mined lands in the Southwest: Symposium proceedings; 1982 October 20-22; Albuquerque, NM; Albuquerque, NM: Soil Conservation Society of America; 1982: 113-118.

Syvertsen, J. P.; Cunningham, G. L.; Feather, T. V. Anomalous patterns of stem xylem water potentials in Larrea tridentata. Ecology. 56: 1423-1428; 1975.

Thames, J. L.; Verma, T. R. Coal mine reclamation on the Black Mesa and the Four Corners areas of Northeastern Arizona. In: Wali, M., ed. Practices and problems of land reclamation in western North America. Grand Forks, ND: University of North Dakota Press; 1975: 48-64.

Tyree, M. T.; Hammel, H. T. The measurement of the turgor pressure and the water relations of plants by the pressure-bomb technique. J. Exp. Bot. 23: 267-282; 1972.

Tyree, M. T.; Richter, H. Alternative methods of analyzing water potential isotherms: some cautions and clarifications. J. Exp. Bot. 32: 643-653; 1981.

U.S. Salinity Laboratory Staff. Diagnosis and improvement of saline and alkali soils. Agric. Handb. 60. Washington, DC: U.S. Department of Agriculture; 1954. 160 p.

Verma, T. R.; Thames, J. L. Grading and shaping for erosion control and vegetative establishment in dry regions. In: Schaller, F. W.; Sutton, P., eds. Reclamation of drastically disturbed lands symposium: Proceedings; 1976 August 9-12; Ohio Agricultural Research and Experiment Station; Wooster, OH; Madison, WI: American Society of Agronomy, Crop Science Society of America, Soil Science Society of America; 1978: 521-535.

Walter, H.; Stadelmann, E. A new approach to the water relations of desert plants. In: Brown, G. W., ed. Desert biology, vol. 1. New York: Academic Press; 1974: 213-310.

Waring, R. D.; Cleary, B. D. Plant moisture stress: Evaluation by pressure bomb. Science. 155: 1248-1254; 1967.

In: Tiedemann, Arthur R.; McArthur, E. Durant; Stutz, Howard C.; Stevens, Richard; Johnson, Kendall L., compilers. Proceedings--symposium on the biology of Atriplex and related chenopods; 1983 May 2-6; Provo, UT. General Technical Report INT-172. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 309 p.

THE GREAT BASIN COLD DESERT: SOME PHYSICAL GEOGRAPHY

Ralph C. Holmgren

ABSTRACT: This paper is a revised version of an invited, informal chat presented at the Wendover, Nevada, overnight stop of the symposium tour. An overview of the geological history, physiography, climate, and hydrology of the eastern Great Basin is presented and used as background in a discussion of the nomenclature of the major regional desert plant associations.

INTRODUCTION

Today, on the first leg of our field tour, we saw in their natural elements some of the chenopodiaceous species whose biology will be discussed in papers later this week. What I propose to talk about tonight is not so much the biology as the elements--earth, water, and air--in which the biology takes place. Let's call this an informal geographical review of the country we traversed today and will see more of tomorrow: the Great Basin cold desert.

The woody-perennial component of family Chenopodiaceae in North America is almost synonymous with this Temperate Zone desert. Chenopodiaceous shrubs are among the dominant species in nearly all of its plant communities. My own desert experience has been a parochial one, so what I have to offer about the physical geography--the abiotic environment--of deserts and how it relates to community distribution applies most particularly to the kind of desert we saw today; that of the northeastern part of the Great Basin.

The variation we see on the desert as expressed by its plant cover derives from the varying influence of four fundamental and, to some degree, interrelated abiotic factors: physiography, geological history, climate, and hydrology. The last two, climate and hydrology, might be considered partial functions of the other two, geology and physiography. A fifth attribute, one of special interest to chenopodiologists, is the distribution of soluble soil salts. It depends directly or indirectly on the other four.

Our cold-desert vegetation has been described and classified by a number of observers over the past century. One very good classification scheme, that of H. L. Shantz of about 60 years ago, seems to have been the most popular and the most durable. But it only seems that way. In reality, it has endured only in some of its nomenclature, nomenclature for the most part long misapplied. It is with regard to the neglect of the descriptive definitions which Shantz provided along with his names for desert plant formations and associations that I want to bring geology and hydrology into the picture. Let us look at these two aspects of the Great Basin desert and rediscover by that physical route what Shantz observed by looking at plant communities: that this land of chenopod dominants is in fact two deserts, one climatic, the other hydrologic, the latter possibly not a desert at all.

GEOLOGY AND PHYSIOGRAPHY

For a very long time, perhaps as long as 600 million years, the crust of the earth in what is now northwestern Utah and northeastern Nevada was comparatively stable. For most of that period it was a marine environment--not an oceanic depth, but shallow-marine. While sediments of muds, limes, and dolomitic materials, and sometimes shoreline sands accumulated to great thicknesses, the shallow sea condition was maintained (with some intervals when the area was above water) presumably by slow crustal subsidence under the gathering weight. The hard rocks we see exposed in our present-day mountains are these ancient (Paleozoic and older) sediments. The exposed strata are in many places much contorted and broken, evidence of a later period of diastrophism that began less than 200 million years ago: uplift and horizontal compression, metamorphism at great depths, folding, faulting, and thrusting. But this great mountain system is not the mountains we see today. Over long ages, the mountains built from materials of the once stable, nearly horizontal, shallow seabed (or sometime lowland) largely eroded away.

Then, much later, beginning about 25 million years ago, in another period of crustal upwarping, less violent and less complicated than the previous one, a broad bulge almost a thousand miles across came into being. It still exists as the highlands known today as the Mountain West. During the early history of this uplift, in places not far from here (Wendover), mostly to the south and west, molten rock rose from great depths through the jumbled sedimentary strata of the roots of the former mountains to erupt and spew volcanic material over the eroded land surface.
Rather late in the history of the regional bulge, its western part, roughly the present area of

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Nevada and western Utah, began to take on the shapes of our present landform. For the past few million years, and continuing even now, vertical slippage of the crust along many almost parallel north-south trending faults, with uplift on one side and downdrop on the other (block faulting), has given us the basin-and-range physiography that characterizes the Great Basin today: a system of long and rather narrow north-south trending mountain ranges separating valleys of similar dimension and orientation. As the mountains have risen, they have also been eroding, and the intervening valleys have filled or partially filled with the outwash material--unconsolidated conglomerate, rubble, sorted and unsorted alluvium of particles ranging in size from boulders down to clays, all derived from the ancient marine strata or, in some valleys, with admixture of volcanics. This fill material, resting on underlying bedrock, may be hundreds of feet thick beneath the present valley floors.

The valleys also collected water. Lakes have undoubtedly come and gone in most of them while the geological structure, the physiography, and the climate have been changing. Evidence of all but the most recent of the lakes is now obscure, having been buried under subsequent valley fill or erased from hillsides where former shorelines stood.

Typically, the valleys today have a wide fringing area of alluvial slopes (fans, bajadas) near the bases of their bordering mountains. The soils high on these slopes, nearer their mountain source, are stoney-gravelly. Valleyward, the material tends to be less and less gravelly: loamy sands, sandy loams, and loams. The central floor of the wider valleys is nearly flat, and in valleys which contained lakes late in the Pleistocene Epoch, the soils may be rather high in clay content. Clayey layers in the material far below the present floor provide evidence of earlier lakes at times when the valley fill was not as deep as it is now.

Some of the Great Basin valleys have no topographic exits for surface water drainage. Thus any waters that flow, as from high-intensity rainstorms or, rarely, from extremely rapid snowmelt, or permanent or seasonal small streams, can go only as far as the lowest part of a valley, where there may be a lake or, more commonly, the bed of an ephemeral lake--a playa--a flat surface of heavy soil bare of vascular plants. Other valleys may have surface water drainage into a lower, neighboring valley. These valleys have structural breaks in their mountain border, or the fill has accumulated to such a level as to bring the floor to the elevation of a pass for outflow. But in our present arid climate no water flows from any of these valleys all the way to the sea. This is a land of interior drainage, a land of many independent one-valley (or few-valley) drainage systems which all together were first called the Great Basin by Captain J. C. Fremont nearly 140 years ago. The only escape for water is by evaporation.

Near the end of the Pleistocene, there were at least a hundred large lakes in the Great Basin valleys. Some were quite deep; some stood at levels high enough for water to spill over mountain passes into other valleys, gaps now high and dry. Most of today's trip was across the bed of former bays and the main body of the largest of the late Pleistocene Great Basin lakes, Lake Bonneville. It was still in existence as recently as 10,000 years ago. Its former shorelines, sculptured by wave action and shore currents while the water surface stood for considerable lengths of time at certain elevations, are readily visible yet as benches, terraces, and seacliffs on the slopes of mountains. Some of these features are hundreds of feet above the present valley floor.

When there was a lake in a valley, the unconsolidated mineral material of the underlying fill would, of course, contain water in the interspaces. And when, in the drier climate of more recent times, the evaporation rate exceeded the rate of water replacement from the atmosphere and the lake finally disappeared, there still remained a substantial subterranean reservoir. Water still continues to move into this reservoir, and excess water from underground storage is still cycling back into the atmosphere. Of course, the rate of turnover is less now, but in a desert valley of average size it is estimated to be a few tens of thousands of acre-feet of water per year.

PRECIPITATION AND SOIL MOISTURE

We are a long way from the ocean and in the rain shadow of distant broad and high mountain ranges which capture most of the moisture from maritime air masses that move this way. In addition, each valley is in the rain shadow of the mountain immediately to its west, the direction from which most of our winter moisture arrives. Hence the desert in the valleys. Fall-to-spring precipitation may be four or more times as much in the mountains as in adjacent valleys. It comes mainly as snow, accumulating over a period of several months, to become available to plants during one short period in the spring when temperatures first become favorable for plant growth. At that season, consistently and reliably, year after year, the soil moisture supply is there and at its highest. The depth of wetting is then also the greatest. Where mountain soils are deeper or thicker over bedrock, there will be more moisture stored, lasting for a longer period of use, and plant cover will be lush. But where the soils are shallow, there is a surplus of water beyond that which can be retained. In some topographic situations, such as those favoring accumulation of wind-driven snow, there can be water in excess of what even the deeper soils can retain. The excess water drains away over or through the underlying bedrock, some of it not to be seen again as it finds its way to a reservoir under a valley, some of it to reappear as spring freshets, intermittent brooks or (in the larger, higher mountains) permanent streams in the canyons. When the water of the little mountain creeks reaches the canyon mouths it does not go very far out onto the alluvial fans before it,

too, disappears, seeping down through the gravels of the streambeds to become part of the groundwater.

Winter moisture in the mountains, then, is the major source of water under the arid valleys. Another upland source is summer storms of such high intensity that much of their rainfall runs overland to gather as torrents in the canyon streambeds and escape sometimes far out onto the fans, but yet mostly sinking into the gravels. Only occasionally do some small amounts flow well out across the valley floor. Just as there are mountains (humid islands, as someone has called them) scattered across the Great Basin, so are there many water-containing catchments under the desert valleys.

As I have already mentioned, the valleys receive only a fraction as much cool- and cold-season precipitation as the mountains. They are winter arid. But, as in the mountains, winter moisture is stored moisture, and when it becomes warm enough in the spring for plants to grow on the desert, there is bound to be water sufficient for some growth. Depending on the amount of precipitation that comes over the winter months, the depth to which the soil is wetted and the amount of water that is stored will vary greatly from year to year. But whatever the amount, it is almost always within reach of roots; a surplus for deeper drainage would be unusual.

There may be moisture enough in spring for growth for a few weeks, or for several, but for summer growth there has to be warm-season precipitation, which on this desert may arrive in effective amounts at times not so predictable as the early spring moisture. Summer rains are unpredictable both as to timing and location, but generally we can expect to have at least one, and usually two or three, periods of monsoonlike storms during the warm months.

With summer storms, there is not the disparity between amounts of water falling on mountains and valleys that we have noted for the winter season. Winter precipitation is distributed orographically, because the air masses at that time move mostly from the west, a direction normal to the axes of the mountains, and lose moisture as they rise to pass over them. Summer storms are convectional from moist air masses which most often move more nearly northward in a direction generally parallel to the mountains. Thus, summer showers, of varying intensity and duration, are almost as likely to occur in the valleys as in the mountains. Both the mountains and the valleys can be considered arid in the warmer months: dry with infrequent, unpredictable, scattered rain. The valleys are more desertic than the mountains because of higher daytime temperatures and greater evaporation stress, as well as the fact that they receive less rain and snow, autumn to spring.

The plant species of the arid valleys are comparatively few. Individual small shrubs and grass plants are widely dispersed, and much ground is exposed. Plant cover is low, ranging from 5 to 15 percent. This kind of desert, living on the rain that falls on it, is one of the two that Shantz pointed out. He labeled it the Northern Desert Shrub Formation and named seven of its "associations," four of which he described as dominated by woody chenopods. We should now go back and consider further the groundwater movements, the Great Basin hydrology, to see a much different situation where we find the second cold desert of Shantz--the one he called the Salt Desert Shrub Formation. Five associations were named and briefly described in the paper where the formation was named; all of them have chenopod shrub dominants.

HYDROLOGY

We have already considered two kinds of topographic valleys: those that are closed, having lakes or playas as the ultimate destination of flowing waters; and those that are open, with drainage into a neighboring valley. Hydrologically, also, as C. T. Snyder has pointed out, there are two general kinds of valleys: those without an underground outlet (the valley fill and its water being contained in a sealed bedrock bowl) and thus having a regional water table very near to or at the ground surface in the lowest parts of the valley; and those where groundwater can escape through subterranean outlets (leaky bowls) and having a water table at depths too great for water loss by evaporation to be significant and usually too deep to be reached by roots. Combining topographic and hydrologic conditions of drainage, we now recognize four general kinds of valleys. Two of them, those with underground drainage, where the regional groundwater surface may be hundreds of feet below the ground surface, have, except in occasional small areas, only the plant associations of the Northern Desert Shrub. The exceptional areas, where species more typical of the Salt Desert Shrub may be found, are areas receiving surface inflow from heavy rains elsewhere, not necessarily every year; and places where local, small, nonregional water tables perched on some underground clayey stratum (possibly related to a lake bed older than late Pleistocene) are near to or intercepted by a sloping ground surface: seepy sites. In these irrigated or subirrigated spots there will be such species as greasewood (Sarcobatus), seepweed (Suaeda), saltgrass (Distichlis), and one or two phreatophytic taxa of rubber rabbitbrush (Chrysothamnus nauseosus).

In the other two kinds of valleys, the ones where groundwater does not leak out, much of the area (lower hills, alluvial slopes, benchlands, and some valley floor) is also Northern Desert Shrub--the climatic desert. It is only on flat lowlands where we find the phreatophyte communities of the Salt Desert Shrub as Shantz described it. The Salt Desert Shrub probably occupies less than half the area of the valleys in which it is important, but in the whole of the Great Basin, its total acreage is substantial. We saw this desert today in the neighborhood of Grantsville, and again on either edge of the barren Great Salt Lake Desert.

Visualize a valley with wide fringing alluvial slopes and a less steeply sloping, almost level valley floor. Visualize also an underground water surface even more nearly level, with whatever slope it may have being toward the very lowest part of the valley. If the valley is drained topographically, this lowest part may be toward one end or near a side of the valley. If the valley has no outlet, the low area will be more centrally located and will be occupied by a playa, white with salt when its surface is dry. The two surfaces, valley bottom and water table, because of their differing slopes are far apart in the area of the bajada and the higher parts of the flatter valley floor. The vadose water is beyond the reach of the most deeply rooted plants, and the desert is climatic. But there is a line, often well-marked by an abrupt vegetation change, that defines the limits of the area in which the water table is within reach of roots. This is where the hydrologic desert starts, and all the associations listed for it by Shantz have as their dominants halophytic phreatophytes.

As the groundwater slowly moves under this desert, its upper layers become more saline the farther it progresses. First the deeper rooted, and then farther on the less deeply rooted, species extract water, leaving a higher concentration of salts as the water table comes into proximity with the ground surface. Commonly, a system of plant communities arranged more or less concentrically around the salty playa is the result. The more deeply rooted and less salt-tolerant species found in the outer bands drop out and other species with greater salt tolerance appear as the distance to the salty playa (or the topographic valley outlet channel) becomes less. Finally there are only pickleweed (Allenrolfia) and samphire (Salicornia), as we saw today, scattered widely at the edge of the playa. The playa itself is an evaporating surface. There are seasonal fluctuations in the level of the water table, and there are infrequent times of higher than average precipitation when the water table is at a higher elevation than the lake bed. At such times, the playa is a lake. Most of the time, however, the playa is simply a flat area of salt crust over heavy, almost always muddy, soil material from which water continues to evaporate and on which salt crystals continue to grow.

SHANTZ'S TWO COLD DESERTS

Now we can take a look at the two deserts Shantz saw and talk about the mischief that has been made of a fine old work of phytosociologic taxonomy. Shantz listed his cold-desert plant communities (he called them associations) approximately in the order of increasing alkali tolerance and, for part of the way through the list, of increasing drought tolerance of the species. But at a point after the seventh of his twelve associations, the order is that of increasing moisture availability and increasing salinity of that moisture.

All of these phreatophyte communities in the Salt Desert Shrub Formation were named for their dominant chenopodiaceous shrubs. But four of the seven associations of the Northern Desert Shrub, his desert that does not rely on supplemental water, are named for chenopods, too. Succeeding ecologists have reasonably recognized several important differences between the sagebrush (Artemisia) associations of Shantz--the associations of the least arid part of his climatic desert--and his other Northern Desert Shrub associations. When these ecologists began to speak of a sagebrush desert zone as a separate entity, this left five Northern Desert Shrub associations to fall by default into the salt desert, apparently because of their chenopodiaceous names. What we have called the Salt Desert Shrub for many years now is no longer the well-defined taxon it once was. An important and readily apparent boundary on the ground was erased in the language.

The logic, I think, goes something like this. The dominant species are chenopods. Chenopods are halophytes. The chenopod-dominated communities, then, are edaphic; salinity modifies the climatic expression of the vegetation. But other workers, notably W. D. Billings, have shown that for some of the so-called halophytes, the presence of salt is not required. Billings also showed that in nonirrigated places where the climate is too arid for sagebrush to grow, chenopods can and do. He suggested that dryland chenopod communities be considered a climatic vegetation zone different from both the less arid sagebrush and what he considered the edaphically controlled salt desert (Shantz's original Salt Desert Shrub). He called his climatic desert the Shadscale Zone. This was a desirable step away from what had become confusion in our communications about cold deserts, but ecologists seem content not to follow. The Billings terminology is little used.

About 15 years ago, F. A. Branson and his coworkers proposed that the communities of watered lowlands not be called desert at all, but salt marsh. This name, slow to catch on, is desirable in that it allow us to toss out the old label "Salt Desert Shrub," which has had an unfortunate history, and use the term salt marsh for the phreatophyte communities found in so many of our climatically arid valleys. Sad to say, however, the Branson group wants to keep the term Salt Desert Shrub, applying it to the original Northern Desert Shrub associations exclusive of the sagebrush--the Shadscale Zone of Billings.

I hope that, as time goes on, we can forego altogether the use of "Salt Desert Shrub" in our discussions, possibly following Billings for a name (Shadscale Zone) for our climatic desert, and Branson (Salt Marsh) for the hydrologic desert, yet somehow not forgetting Shantz, who pointed out the distinction long ago.

Three things we should remember about the Salt Desert Shrub are: First, when we see or hear the term, we should look for or ask to have a descriptive definition of what is implied. Second, the old salt desert, now perhaps salt marsh, is not a desert in a climatic sense and can be found in climates where no neighboring communities are desertic. Third, in the Great

Basin, it usually is marked on its outer edge by the presence of greasewood and extends downward elevationally from there. As you travel in a number of valleys, you will notice that it is a distinct formation clearly defined by color and physiognomy. If there is a playa in its midst, its dry surface will be white rather than the light buff color of desert soil. And if you are traveling longitudinally in a valley having this "marsh desert", it will be the vegetation you see on the lower side of the road.

BACKGROUND REFERENCES

Plant Community Classification and Nomenclature

Billings, W. D. The plant associations of the Carson Desert region, western Nevada. Butler Univ. Bot. Studies. 8: 89-123; 1945.

Billings, W. D. The shadscale vegetation zone of Nevada and eastern California in relation to climate and soil. Am. Midland Nat. 42: 87-109; 1949.

Branson, F. A.; Miller, R. F.; McQueen, I. S. Geographic distribution of salt desert shrubs in the United States. J. Range Manage. 20: 287-293; 1967.

Fautin, R. W. Biotic communities of the northern desert shrub biome in western Utah. Ecol. Monogr. 16: 250-310; 1946.

Fireman, M.; Hayward, H. E. Indicator significance of some shrubs in the Escalante Desert. Utah. Bot. Gaz. 114: 143-155; 1952.

Kearney, T. J.; Briggs, L. J.; Shantz, H. L.; McLane, J. W.; Piemeisel, R. L. Indicator significance of vegetation in Tooele Valley, Utah. J. Agric. Res. 1: 365-417; 1914.

Kuchler, A. W. Potential natural vegetation of the conterminous United States. Am. Geogr. Soc. Publ. 361. Washington, DC: American Geographical Society; 1964. 116 p. and map.

Shantz, H. L. Plant communities in Utah and Nevada. In: Tidestrom, I. Flora of Utah and Nevada. Contrib. U.S. Natl. Herbarium No. 25. Washington, DC: Smithsonian Institution; 1925: 15-23.

Shelford, V. E. The ecology of North America. Urbana, IL: University of Illinois Press; 1963. 610 p.

Shreve, F. The desert vegetation of North America. Bot. Rev. 8: 195-146; 1942.

Stewart, G.; Cottam, W. P.; Hutchings, S. S. Influence of unrestricted grazing on northern salt desert plant associations in western Utah. J. Agric. Res. 60: 289-316; 1940.

Vest, E. D. Biotic communities in the Great Salt Lake desert. Ecol. and Epizool. Serv. 73. Salt Lake City, UT: University of Utah, Institute of Environmental and Biological Research; 1962. 122 p.

Weaver, J. E.; Clements, F. E. Plant ecology. New York: McGraw-Hill; 1938. 601 p.

West, N. E. Intermountain salt-desert shrublands. In: West, N. E., ed. Ecosystems of the world. Vol. 5. Amsterdam: Elsevier Scientific; 1982: 375-398.

Geology, Geomorphology

Fenneman, N. M. Physiography of the western United States. New York: McGraw-Hill; 1931. 534 p.

Hintze, L. F. Geologic history of Utah. Geology Studies Vol. 20, Pt. 3. Provo, UT: Brigham Young University; n.d. [1977?]. 189 p.

Hubbs, C. L.; Miller, R. R. The zoological evidence--correlation between fish distribution and hydrographic history in the desert basins of western United States. In: The Great Basin: with emphasis on glacial and postglacial times. Biol. Ser. Vol. X, No. 7. Bull. of Univ. of Utah. Salt Lake City, UT: University of Utah; 1948; 38: 17-166.

Nolan, T. B. The Basin and Range Province in Utah, Nevada, and California. Prof. Pap. 197-D. Washington, DC: U.S. Department of the Interior, Geological Survey; 1943: 141-196.

Snyder, C. T.; Hardman, G.; Zdenek, F. F. Pleistocene lakes in the Great Basin. Misc. Geol. Investig. Map I-416. Washington, DC: U.S. Department of the Interior, Geological Survey; 1964.

Thornberry, W. D. Regional geomorphology of the United States. New York: John Wiley; 1965. 609 p.

Hydrology

[Note: Numerous investigations of the groundwater resource in the Great Basin valleys have been made in the past 70 years. Contained in the hydrologic literature is a mine of information on native plant distribution as related to plant-root proximity to (and salinity of) imported water which few ecologists and plant geographers seem to be aware of. Meinzer, in 1917, said "Groundwater discharge is shown with considerable fidelity by plants of certain species that are found almost exclusively in shallow-water districts." He said our vegetation can be put into three "groups"--we can call them formations or zones--and he listed a zonation of dominant plant species in much the order that ecologists have done. Meinzer added that water discharge areas could be mapped "with nearly as much precision as rock outcrops" by using these vegetation indicators; and many subsequent reports do indeed have such detailed maps.

In the early years, groundwater investigation was largely the province of the U.S. Geological Survey, but there are also now available many reports issued by State resource departments, water departments, and engineers' offices for Nevada, Utah, and California. I list below only a few, some of several which in my estimation are valuable contributions to a better understanding of Great Basin plant ecology.]

Loeltz, O. J.; Eakin, T. E. Geology and water resources of Smith Valley, Lyon and Douglas Counties, Nevada. Water-Supply Paper 1228. Washington, DC: U.S. Department of the Interior, Geological Survey; 1953. 89 p.

Meinzer, O. E. Geology and water resources of Big Smoky, Clayton, and Alkali Spring Valleys, Nevada. Water-Supply Paper 423. Washington, DC:

U.S. Department of the Interior, Geological Survey; 1917. 167 p.
Mower, R. W.; Feltis, R. D. Ground-water hydrology of the Sevier Desert, Utah. Water-Supply Paper 1854. Washington, DC: U.S. Department of the Interior, Geological Survey; 1968. 75 p.
Snyder, C. T. Hydrology of stock-water development on the public domain of western Utah. Water-Supply Paper 1475-N. Washington, DC: U.S. Department of the Interior, Geological Survey; 1963: 487-536.
Utah Department of Natural Resources. [At least 100 technical bulletins, water circulars, basic-data reports, and information bulletins, mostly concerned with the Great Basin half of Utah, and many of which discuss groundwater inflow, quality, movement, and discharge, have been issued since 1944.]

In: Tiedemann, Arthur R.; McArthur, E. Durant; Stutz, Howard C.; Stevens, Richard; Johnson, Kendall L., compilers. Proceedings--symposium on the biology of Atriplex and related chenopods; 1983 May 2-6; Provo, UT. General Technical Report INT-172. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 309 p.

Section 3. Physiology

CHANGES IN FREE AMINO ACIDS AND GUANOSINE NUCLEOTIDES IN ATRIPLEX CANESCENS (PURSH)[NUTT.] DURING WATER STRESS

William A. Cress

ABSTRACT: Water stress of *Atriplex canescens* seedlings resulted in changes in levels of several nonbound amino acids. Glutamate decreased from 12 µmol. per gram fresh weight to an undetectable level. Asparagine increased from 16 to 30 µmol. per gram fresh weight. An overall decrease in guanosine nucleotides of 32 percent was noted. The decrease in glutamate and in guanosine nucleotide contents along with an increase in asparagine content during water stress suggest a cause-effect relationship between the decrease in glutamate and the decrease in polysomes during water stress.

INTRODUCTION

A number of metabolic changes occur when plants are subjected to water stress. These include: an increase in total free amino and imino acids (Barnett and Naylor 1966), an increase in amides (Barnett and Naylor 1966; Thompson and others 1966), an increase in quarternary amines such as the betaines (Hanson and others 1978), and an increase in abscisic acid (Milborrow 1974). There has been much speculation as to whether the production of stress metabolites, compounds which increase in concentration under stress, is a protective mechanism associated in some way with tolerance to increasing levels of stress or whether these compounds are only indicators that a plant has been subjected to stress and are not protection-related.

Proline, a protein imino acid, has been reported to increase in plants during mild to severe stress (Kemble and MacPherson 1954). This increased content can be induced by drought, cold, or salt stress, and therefore appears to be a general stress response. Research on proline's effect on stress tolerance (Kemble and MacPherson 1954; Barnett and Naylor 1966; Singh and others 1972; and Stewart and others 1966) has led to speculation that proline acts as an osmoticum to reduce water loss through evapotranspiration or that it is used as a storage form of organic nitrogen available for rapid recovery and growth after relief from water stress.

Recent research indicates the actual function of proline during water stress may be to stabilize enzyme structure against heat denaturation (Nash and others 1982). This would result in the protection of critical metabolic pathways needed for plant recovery and growth after water stress.

The work of Paleg and others (1981) and Nash and others (1982) in Australia has shown that at temperatures of 38-54°C proline can protect enzymes from heat denaturation.

Atriplex canescens (Pursh)[Nutt.] does not accumulate large quantities of free proline during moisture stress (Cress 1982). It was therefore of interest to determine whether greater concentrations of free protein amino or imino acids occur during moisture stress. Several protein amino and imino acids have been shown to accumulate in plant tissue during moisture stress. Total asparagine accumulation is second only to proline during moisture stress (Thompson and others 1966).

Also of interest in moisture stress studies are reports of stress-induced reduction in numbers of polysomes (Hsiao 1970); reductions possibly correlated to the observed changes in free amino acids during moisture stress.

METHODS

Atriplex canescens seed were germinated in soil in 1-quart plastic pots in a greenhouse. Soil was maintained at field capacity during germination at 34-39°C days and 27-28°C nights. The soil for the study, collected from the Burnam Mine in northwestern New Mexico, was a composite of the A and B horizons. Fifteen days after seedling emergence, water was withheld from plants in the stress treatment. Control plants were watered regularly to prevent drying of the soil. At the end of 7 additional days, both control and stressed plant materials were analyzed. All shoots in each pot (10 to 15 plants per pot) were composited into one sample and the fresh weight measured. The moisture content of the soil on an ovendry basis was also determined

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at the time of harvest. For free amino acid analysis, the composited samples were suspended in methanol: chloroform: water (12:5:3) and disrupted in a Sorvall Omni-mixer.

For free amino acid analysis, the amino acids were extracted from the composite samples, converted to their Phenythiohydantoin (PTH) derivatives, and analyzed on a Hewlett-Packard 1084B Liquid chromatagraph using an Altex Ultrasphere ODS (PTH) column (Moser and Rickli 1979). The study was done twice with three replications per treatment. For the nucleotide analysis, the individual plants (either moisture stressed or nonstressed) were extracted and the nucleotides analyzed on the 1084B Chromotograph using a Bio-Sil TSK 1EX-540 DEAE column. The nucleotide study was performed twice with four determinations per treatment. Statistical comparison of treatments was accomplished using the t-test. Significance was assured at $p=0.05$.

RESULTS AND DISCUSSION

The soil water content for the stressed treatment was 1.9 + 0.2 percent, and for the nonstressed pots 6.5 + 0.4 percent. Based on the ceramic plate method of soil water potentials, the osmotic potential of the stressed and nonstressed soil was -5.5 and -0.06 MPa respectively based on the soil water content.

The changes in free amino and imino acids during the 7 days of water stress are shown in table 1. Of the amino acids (cysteic, aspartic, glutamic, serine, tyrosine, and tryptophan), only glutamic acid decreased significantly with stress. It decreased from 12 µmol. per gram fresh weight to a nondetectable level. Asparagine, proline, and methionine all increased under water stress, but only asparagine showed a significant increase--from 16 to 30 µmol. per gram fresh weight. Glutamine, glycine, alanine, arganine, and phenylalanine were all present at concentrations of less than 0.01 µmol. per gram fresh weight; concentrations were barely detectable and therefore not quantified. Threonine, histidine, hydroxyproline, valine, isoleucine, leucine, and lysine were not detectable.

Contents of the free guanosine nucleotides (table 2), mono-, di-, and tri-phosphates, decreased in the moisture stressed plants. Only the decrease in guanosine 5-triphosphate was significant. The decrease in total guanosine nucleotides was 32 percent.

The pathways for biosynthesis of the nucleotides are shown in fig. 1. The important intermediates are glutamate, glutamine, and aspartate. Of these three amino acids, only glutamate significantly decreased in the pool of free amino acids during water stress. It is the key branch point for the flow of carbon from the tricarboxilic acid (TCA) cycle via 2-oxy-glutarate to the nucleotides during their biosynthesis. The increase in asparagine from 16 to 30 µmol. per gram fresh weight during the stress period shows one possible product to which the carbon flow was channeled during water stress.

The decrease in polysomes during water stress has been well documented (Hsiao 1970; Morilla and others 1973), but a direct cause-effect relationship has not been demonstrated. The requirement of guanosine 5-triphosphate for the binding of the ribosomes to messenger RNA, and thus the formation and maintenance of polysomes, suggests that a loss of guanosine 5- triphosphate due to water stress would result in a loss of polysomes. The reduction in glutamate with the resulting loss of guanosine nucleotides, particularly guanosine 5-triphosphate, is therefore suggested as one direct cause of the loss of polysomes during water stress.

CONCLUSIONS

Considerable research has addressed the question of what mechanism regulates the biosynthesis of protein during water stress. The present study on changes in free amino acids and nucleotides during water stress in A. canescens suggests that during water stress the biosynthesis of protein is inhibited due to a loss of polysomes when the carbon necessary for the synthesis of guanosine tri-phosphate is channeled into asparagine.

Since guanosine tri-phosphate is necessary for the initiation step in the formation of the polysomes which synthesize proteins it is likely that their loss is the direct cause of the cessation of protein synthesis during water stress.

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Table 1.--Changes in content of free amino acids in <u>Atriplex canescens</u> in water stressed versus nonstressed shoots.

Amino acid	Nonstressed	Stressed 7 days
	---------- μmol./g fresh weight ----------	
Cysteic	[1]0.47 ± 0.30	0.27 ± 0.07
Aspartic	0.12 ± 0.16	0.02 ± 0.01
Glutamic	[2]12.11 ± 9.76	(3)
Serine	5.21 ± 4.33	2.11 ± 0.90
Tyrosine	0.42 ± 0.10	0.07 ± 0.03
Tryptophan	4.03 ± 2.72	1.08 ± 0.53
Asparagine	[4]16.24 ± 3.18	30.24 ± 6.90
Proline	0.08 ± 0.04	0.11 ± 0.02
Methionine	0.03 ± 0.02	0.06 ± 0.04
Glutamine	(4)	(4)
Glycine	(4)	(4)
Alanine	(4)	(4)
Arganine	(4)	(4)
Phenylalanine	(4)	(4)
Threonine	(3)	(3)
Hydroxy proline	(3)	(3)
Valine	(3)	(3)
Isoleucine	(3)	(3)
Lysine	(3)	(3)
Leucine	(3)	(3)

[1]Means and standard deviations of 6 determinations.

[2]The nonstressed treatment is significantly different from the stressed treatment at the p=0.05 level using the t-test.

[3]Present at concentration of less than 0.01 μmol. per gram fresh weight (not quantifiable).

[4]Not detectable.

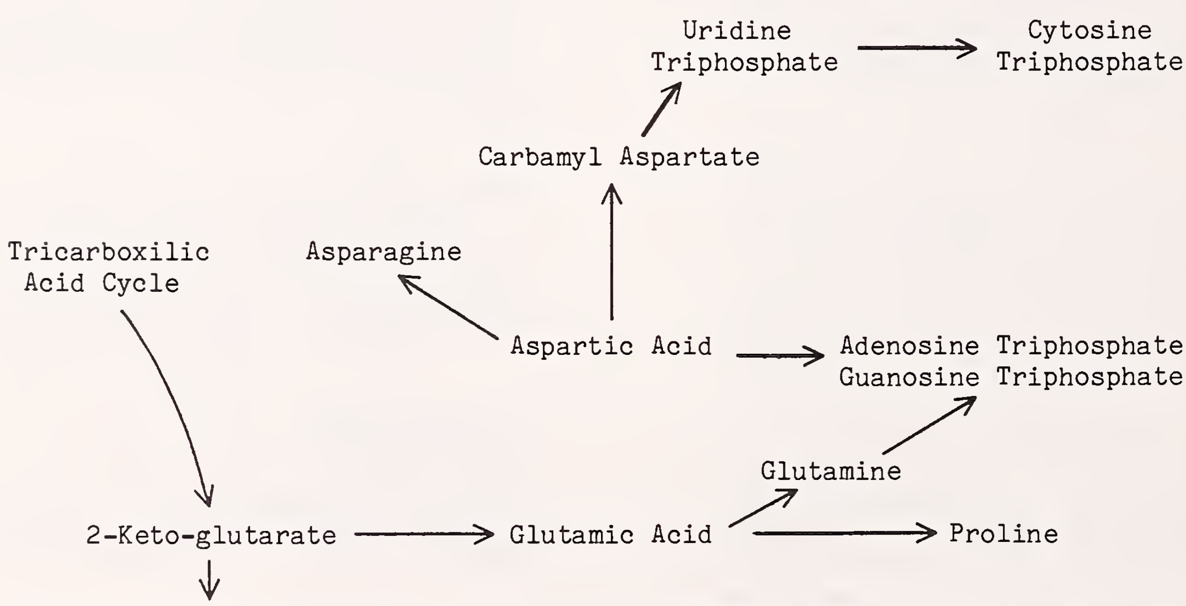

Figure 1.--The biosynthesis of the nucleotides from the TCA-cycle via their amino acid precursors.

Table 2.--Changes in content of free guanosine nucleotides in *Atriplex canescens* water stressed versus nonstressed shoots.

Nucleotides	Nonstressed	Stressed 7 days
	------------ μmol./g fresh weight	------------
Guanosine mono-phosphate	[1]9.05 ± 2.14	7.19 ± 2.13
Guanosine di-phosphate	[2]5.17 ± 1.37	3.44 ± 1.70
Guanosine tri-phosphate	[2]5.99 ± 0.89	2.99 ± 1.32
Total guanosine nucleotides	[2]20.21 ± 2.69	13.62 ± 2.52

[1]Means and standard deviations of eight determinations.

[2]The nonstressed treatment is significantly different from the stressed treatment at the p=0.05 level using the t-test.

PUBLICATIONS CITED

Barnett, N. M.; Naylor, A. W. Amino acid and protein metabolism in Bermuda grass during water stress. Plant Physiol. 41: 1222-30; 1966.

Cress, W. A. The effect of varied watering regimens on proline production in *Atriplex canescens*, *Hilaria jamesii*, and *Agropyron smithii*. In: Aldon, E. F.; Oaks, W. R. eds. Reclamation of mined lands in the Southwest symposium; Proceedings; 1983 October 20-22; Albuquerque, NM: SCSA New Mexico chapter; 1983. p 165-169.

Hsiao, T. C. Rapid changes in levels of polyribosomes in *Zea mays* in response to water stress. Plant Physiol. 46: 281-285; 1970.

Hanson, A. D.; Nelsen, C. E.; Ladyman, J. A. R. Betaine accumulation in water-stressed barley leaves. Plant Physiol. (Suppl.) 61: 81; 1978. Abstract.

Kemble, A. R.; MacPherson, H. T. Liberation of amino acids in perennial rye grass during wilting. Biochem. J. 58: 46-49; 1954.

Milborrow, B. V. The chemistry and physiology of abscisic acid. Annu. Rev. Plant Physiol. 25: 259-307; 1974.

Morilla, C. A.; Boyer, J. S.; Hageman, R. H. Nitrate reductase activity and polyribosomal content of corn (*Zea mays* L.) having low leaf water potentials. Plant Physiol. 51: 817-824; 1973.

Moser, P. W.; Rickli, E. E. Identification of amino acid phenylthiohydantoins by gradient, highperformance liquid chromatography on Spherisorb S5-ODS. J. Chromatogr. 176: 451-455; 1979.

Nash, D.; Paleg, L. G.; Wiskich, J. T. Effect of proline betaine and some other solutes on the heat stability of mitochondrial enzymes. Aust. J. Plant Physiol 9: 47-57; 1982.

Paleg, L. G.; Douglas, T. J.; VanDall, A.; Keech, D. B. Proline, betaine and other organic solutes protect enzymes against heat inactivation. Aust. J. Plant Physiol. 8: 107-114; 1981.

Singh, T. N.; Aspinall, D.; Paleg, L. G. Proline accumulation and varietal adaptability to drought in barley: a potential metabolic measure of drought resistance. Nature (New Biology) 236: 188-190; 1972.

Stewart, C. R.; Morris, C. J.; Thompson, J. F. Changes in amino acid content of excised leaves during incubation. II. Role of sugar in the accumulation of proline in wilted leaves. Plant Physiol. 41: 1585-1580; 1966.

Thompson, J. F.; Stewart, C. R.; Morris, C. J. Changes in amino acid content of excised leaves during incubation. I. The effect of water content of leaves and atmospheric oxygen level. Plant Physiol. 41: 1578-1584; 1966.

In: Tiedemann, Arthur R.; McArthur, E. Durant; Stutz, Howard C.; Stevens, Richard; Johnson, Kendall L., compilers. Proceedings--symposium on the biology of *Atriplex* and related chenopods; 1983 May 2-6; Provo, UT. General Technical Report INT-172. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 309 p.

APPLICATION OF A WATER-BALANCE, CLIMATE MODEL FOR RESEARCH AND MANAGEMENT IN A DESERT-SHRUB COMMUNITY

J. Ross Wight

ABSTRACT: This paper discusses research and management applications of a model that simulates the soil water and soil temperature regimes, evaporation, and transpiration on a daily basis. The ratio of actual to potential transpiration provides an index of annual growing conditions based on soil water availability and evapotranspiration demand. This index can be used to compare growing conditions among years or among sites, account for the effects of climate in monitoring changes in plant communities, or evaluate treatment effects. Long-term simulations are possible. Simplicity enhances the model's application.

INTRODUCTION

Rangeland models are becoming increasingly important as research and management tools. They provide a systematic way of synthesizing and organizing information. They enhance the analysis and understanding of complex systems. Where models satisfactorily mimic the real world, effective research can be accomplished by performing experiments on the models rather than in the field. Through the process of simulation, variables such as soil water and soil temperature can often be estimated with sufficient accuracy to preclude the need for routine field measurements. As models are able to simulate the processes within an ecosystem, they also become effective tools for resource managers.

Rangeland models vary in complexity and resolution of output. They range from comprehensive ecosystem models such as ELM (Innis 1978), ELMAGE (Pendleton and others 1983), and SPUR (Wight 1983), to models such as ERHYM (Wight and Neff 1983) that consider the range as a monoculture and predict total herbage yield on the basis of water stress. The amount of information needed and complexity of operation are directly related to the complexity of the model.

This paper discusses ERHYM, a physically-based model that is relatively simple to operate, and its application to problems of research and management. While only ERHYM will be discussed in this paper, its application to problems of research and management is typical of predictive models, and its application to desert-shrub communities is essentially the same as for other plant communities.

MODEL DESCRIPTION

The model discussed in this paper has been described by Wight and Hanks (1981), and Wight and Neff (1983). It is site-specific and operates on a daily time-scale. Inputs include an estimate of potential evapotranspiration (ET); daily precipitation; a transpiration coefficient; parameters for calculating a relative growth curve; and the initial soil water content, field capacity, and wilting point for each soil layer. Potential ET is calculated from daily solar radiation and average air temperatures (Jensen and Haise 1963). The transpiration coefficient can be estimated from the peak standing crop as described by Wight and Neff (1983). The relative growth curve is simply the seasonal change in live standing phytomass based on a scale of 0.0-1.0, where 1.0 represents peak standing crop.

Model outputs, calculated on a daily basis, include potential transpiration (T_p), actual transpiration (T_a), potential soil evaporation, actual soil evaporation, and soil water content by soil layer. These outputs can be mixed in various combinations to provide other information such as actual and potential evapotranspiration (ET) and T_a/T_p.

MODEL APPLICATIONS

Model outputs applicable to research needs include daily soil water content, ET, T_a/T_p, and soil temperatures. Figures 1, 2, and 3 show comparisons of field-measured and model-predicted values of soil water content, ET, and soil temperature, respectively, for a sagebrush dominated range site in southwestern Idaho. In general, there is good agreement between the model-predicted and field-measured values. Some of the discrepancies in the soil temperature and comparisons are due to the fact that the model-

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predicted values represent daily means, and the field-measured values represent single, midday readings. Variables such as ET, T_a/T_p, and soil temperature are directly related to plant growth, and the availability of accurate model-predicted values can often reduce the need for field measurements, thus reducing both labor and instrumentation expenses.

A yield index, expressed as T_a/T_p, provides an effective means of quantifying soil water-precipitation-temperature relationships as they affect plant growth. T_a/T_p is generally better correlated to plant growth than either precipitation or combinations of precipitation and soil water because it also takes into account the evaporative demand and the distribution of water stress throughout the growing season. A T_a/T_p value of 1.0 indicates that water was nonlimiting during the growing season and that the yield should be the potential maximum for that site. Wight and Hanks (1981) reported a linear relationship between T_a/T_p and peak standing crop. They also found that T_a/T_p was more closely correlated to herbage yields than either T_a or ET.

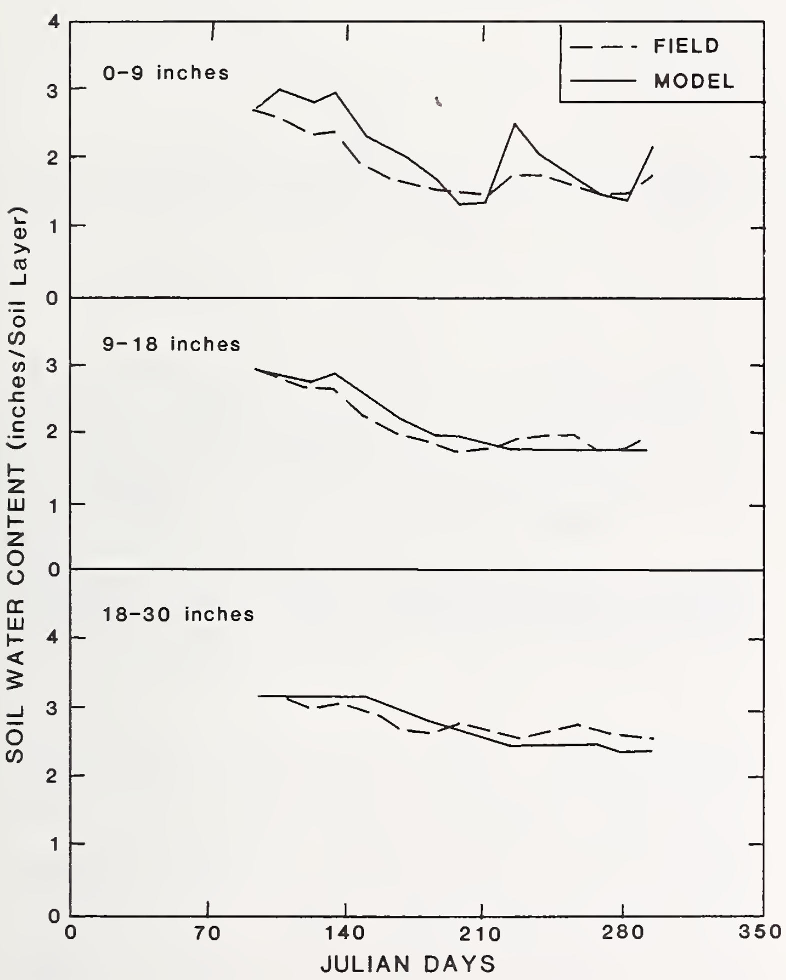

Figure 1.--Field-measured and model-predicted soil water profiles for a sagebrush-grass range site in southwestern Idaho, 1979.

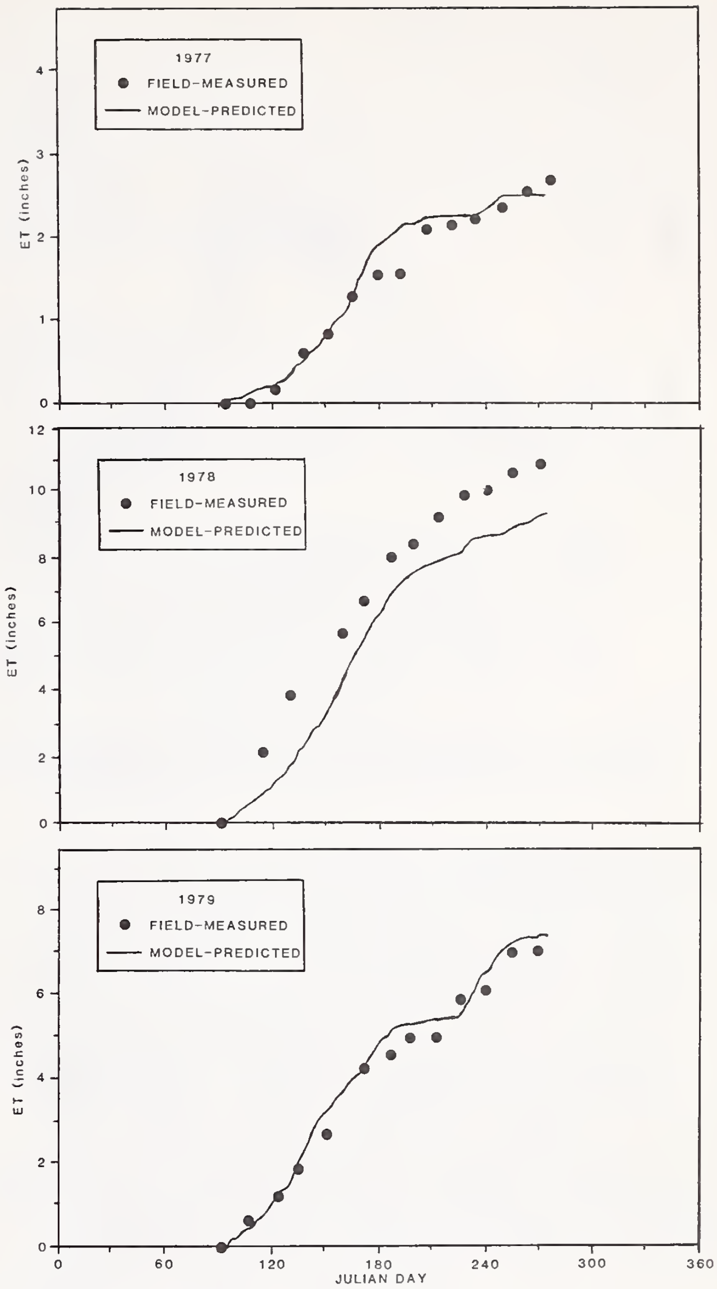

Figure 2.--Field-measured (from soil water and precipitation data) and model-predicted cummulative ET for a sagebrush-grass range site in southwestern Idaho.

The use of yield indices to quantify growing seasons in terms of water stress provides a means for comparing research results among sites and among years by removing the confounding effects of climate. For example, forage production from a wet year can be compared with forage production from a relatively dry year by normalizing the data on the basis of a yield index. Assuming a linear relationship between the yield index and yield, 300 lb/acre (336 kg/ha) yield produced in a growing season with a yield index of 0.5 is comparable to a 600 lb/acre (672 kg/ha) yield produced in growing season with a yield index of 1.0. The difference of 300 lb/acre (336 kg/ha) between growing seasons can be accounted for by climatic effects rather than treatment or management effects.

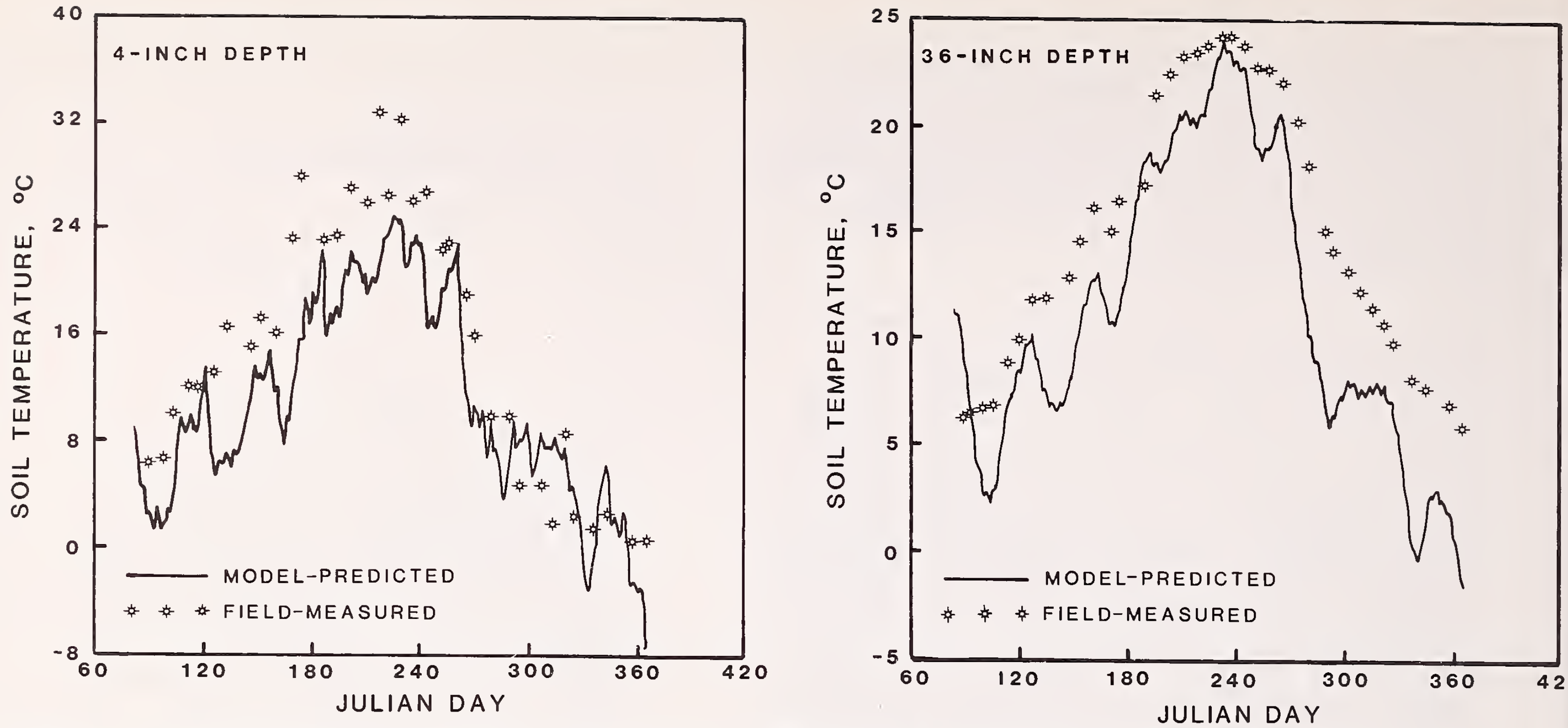

Figure 3.--Field-measured and model-predicted soil temperature profiles for 4-inch and 36-inch depths, respectively, for a sagebrush-grass range site in southwestern Idaho, 1981.

There are three areas in which models such as this can be directly applied to management: (1) prediction of annual forage production with real time data, (2) monitoring forage yield as an indication of trend, and (3) forecasting herbage production. Using the relationship actual yield/ potential yield = T_a/T_p, peak standing crop for a given site can be readily calculated as the product of the T_a/T_p yield index and the potential yield of that site. The potential yield of a site is the yield that would occur on that site in its present condition, when water was non-limiting. It does not refer to potential yields attainable with enhancements such as fertilization or reseeding. Table 1 and figure 4 show the relationships between the yield index and field-measured yield values for a sagebrush-grass and mixed prairie range site, respectively. The model has proved reasonably effective for mixtures of perennial grasses, shrubs, and forbs, but may be ineffective for predicting yields of annual plants where yields are directly related to varying plant populations. It has no mechanism to account for seedling establishments.

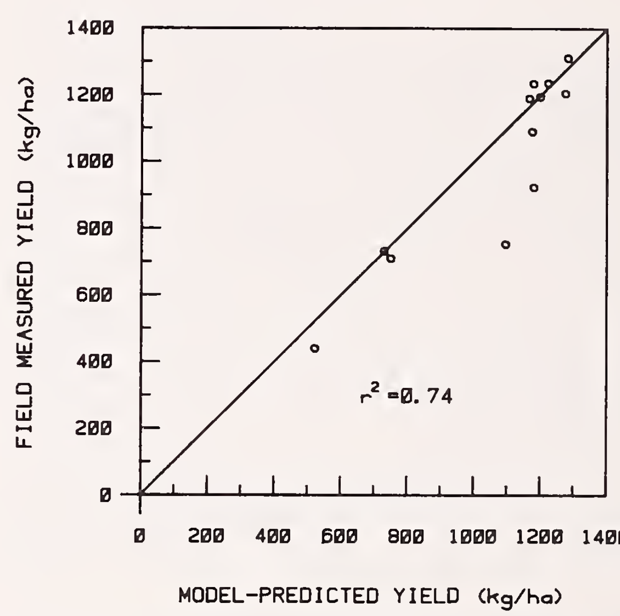

Figure 4.--Relationship between field-measured and model-predicted herbage yields for 1967-78, Sidney, Mont. (Wight and Hanks 1981)

Table 1. Comparison of model-predicted and field-measured yields for a sagebrush-grass range site in southwestern Idaho

Year	Model-predicted	Field-measured
1976	731	582
1977	286	307
1978	731	934
1979	717	780
Mean	616	651

For determining trend, the model-calculated yield index can be used to normalize data from succeeding years to remove the variability due to climate. This is demonstrated in figure 5a, where field-measured and model-predicted yields are plotted for a 10-year period. There is a wide variation in field-measured yields. This reflects climate and possibly management effects; no trend is apparent. The variation in model-predicted yields reflects only the climatic effects. Thus, the differences in field-measured and model-predicted yields can be used to indicate management induced trend. In figure 5b, the annual ratio of field-measured/model-predicted yields became increasingly less than 1.0 indicating a downward trend.

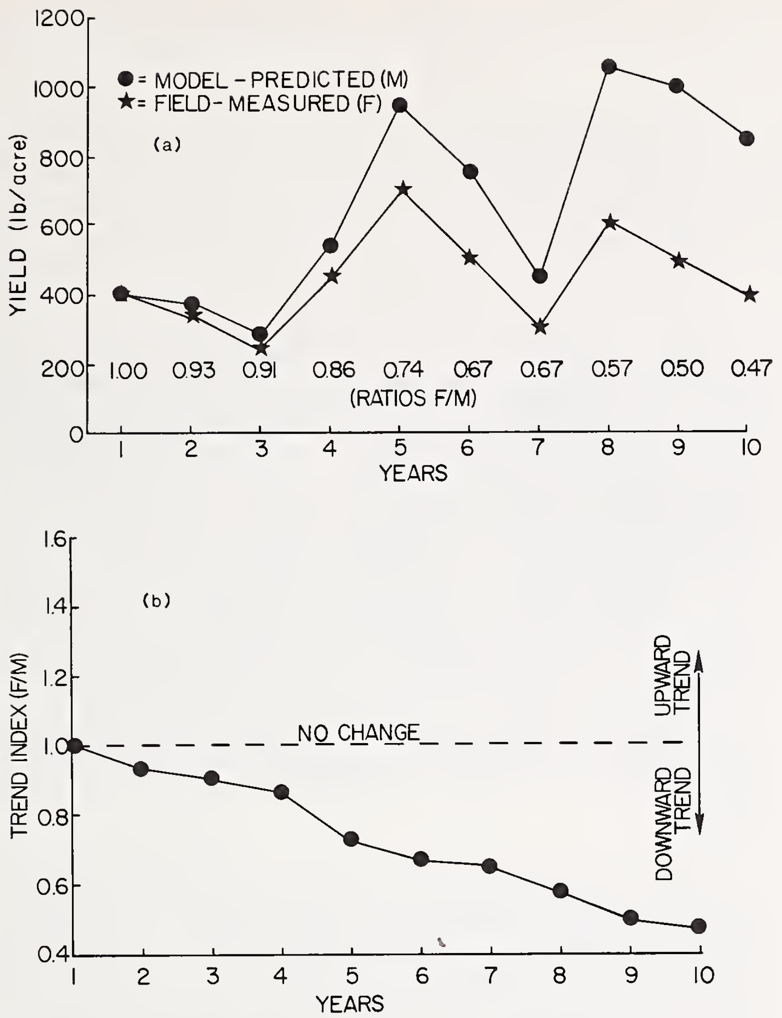

Figure 5.--(a) Hypothetical field-measured and model-predicted yields and (b) the use of their ratios (F/M) to determine management induced trend.

Yield indices can be used in conjunction with long-term weather records or a stochastic weather generator such as that used in SPUR (Wight 1983) to forecast the current year's herbage production at the beginning of the growing season (Wight and others 1984). By using the current year's initial soil water content and the daily precipitation and mean temperatures from past weather records, a yield index can be calculated for each year of the weather record. This results in yield indices that represent only variations in weather. The indices are normally distributed. A mean, with confidence intervals, can be calculated as the current year's yield forecast where yield is the product of the mean yield index (T_a/T_p) and the yield potential for that site. Using the standard deviation as the confidence interval, we establish a 68 percent probability that the current year's actual yield will be within a standard deviation of the forecasted yield. Yield forecasts can be updated periodically during the growing season by using the current year's weather records up to the date of forecast and past weather records from that date to peak standing crop.

With the development of comprehensive management models such as SPUR, management options such as grazing intensity or improvement practices such as seeded pastures can be evaluated in terms of plant and animal response, economic returns, and runoff and erosion impacts through the process of simulation. The future will, no doubt, see more application of modeling technology in rangeland research and management.

PUBLICATIONS CITED

Innis, G. S., ed. Grassland simulation model. Ecological Studies 26. New York: Springer-Verlag; 1978. 1-298.

Jensen, M. E.; Haise, H. R. Estimating evapotranspiration from solar radiation. American Society of Civil Engineers Proceedings. Journal of the Irrigation and Drainage Division 89:15-41; 1963.

Pendleton, Dennis F.; Menke, John W.; Williams, William A.; Woodmansee, Robert G. Annual grassland ecosystem model. Hilgardia 51(1): 1-44; 1983.

Wight, J. R., ed. 1983 SPUR--Simulation of Production and Utilization of Rangelands: a rangeland model for management and research. Misc. Publ. 1431. Washington, D.C.: U.S. Department of Agriculture; 1983. 120 p.

Wight, J. R.; Hanks, R. J. A water-balance, climate model for range herbage production. J. Range Manage. 34(4): 307-311; 1981.

Wight, J. R.; Hanson, C. L.; Whitmer, D. Using weather records with a forage production model to forecast range forage production. J. Range Manage. 37(1): 3-6; 1984.

Wight, J. R.; Neff, E. L. Soil-vegetation-hydrology studies. Vol. II. A user manual for ERHYM: The Ekalaka Rangeland Hydrology and Yield Model. ARR-W-29. Washington, D.C.: U.S. Department of Agriculture, Agricultural Research Service, 1983. 30 p.

In: Tiedemann, Arthur R.; McArthur, E. Durant; Stutz, Howard C.; Stevens, Richard; Johnson, Kendall L., compilers. Proceedings--symposium on the biology of Atriplex and related chenopods; 1983 May 2-6; Provo, UT. General Technical Report INT-172. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 309 p.

THE EFFECT OF SALINITY ON THE IONIC CONTENT AND

WATER RELATION OF ATRIPLEX TRIANGULARIS WILLD.

S. H. Karimi and I. A. Ungar

ABSTRACT: Survival and growth in saline environments is dependent upon plants reaching a favorable water balance. Measurements under various salinity conditions indicate that Atriplex triangularis Willd. maintains a more negative water potential, osmotic potential, and shoot xylem pressure potential than its root media. Root xylem pressure potentials were always less negative than those of the shoot. Highest leaf turgor pressure was achieved in moderately saline conditions; increased salinity decreased the leaf pressure potential. Accumulation of Na+ and Cl- ions in the leaves is probably the chief mechanism for lowering the leaf osmotic potential. Less negative shoot xylem osmotic potential suggests that leaves may remove ions rapidly from the xylem sap.

In order to cope with the high salt concentrations in its natural environment, A. triangularis appears to employ the following strategies: first, low root xylem pressure potential indicates the root regulates ion influx into the plant in higher salinities; second, abscission of very old leaves, which appear to have Na+ and Cl- ion concentrations similar to those of young leaves, serves as a mechanism for the removal of ions; third, functional salt hairs are found only in young leaves and serve as a mechanism for the removal of excess ions; and fourth, increased succulence appears to be the principal mechanism for osmoregulation in mature leaves.

INTRODUCTION

A number of attempts have been made to classify halophytes based on their mechanism of salt tolerance (Waisel 1972; Albert 1975; Caldwell 1974). Three categories are widely used: salt accumulators, salt evaders, and salt excluders (Flowers and others 1977; Schirmer and Breckle 1982). Although there are halophytes which may fit each category, distinctions among these groups are difficult to sustain (Osmond and others 1980). Atriplex species exhibit a number of anatomical and physiological features that facilitate the survival of the plant in saline environments.

Mineral accumulation in aerial organs is a common phenomenon observed in the genera that inhabit saline environments. Inorganic ions account for over 25 percent of leaf dry weight in a number of Atriplex species growing in saline media (Ashby and Beadle 1957; Wood 1937). Accumulation of high quantities of ions can produce a negative leaf osmotic potential, thus assuring a water potential gradient. Such high concentrations of minerals are likely to have an adverse effect on plant growth and development (Flowers and others 1977). Halophytes employ two mechanisms to avoid the detrimental effects of high tissue mineral content: first, dilution of mineral concentration in leaves is achieved through increased succulence (Sharma 1982; Gale and Poljakoff-Mayber 1970); and second, salt excretion regulates the electrolyte content of leaves (Liphschitz and Waisel 1982).

A common anatomical feature shared by all Atriplex species studied so far is the presence of vesiculated epidermal hairs on leaves. These structures, which are also called salt hairs, salt bladders, and epidermal trichomes, play an important role in the overall salt economy of these taxa (Schirmer and Breckle 1982). About half of the leaf minerals may be contained in these structures.

Some halophytes are also known to have developed avoidance mechanisms (Waisel 1972). Avoiders are very selective in their ion uptake and, as a result, maintain a low internal concentration of minerals (Scholander and others 1966). However, recent studies indicate that selective uptake of minerals appears to be important in ion regulation of some Atriplex species (Breckle 1974; Ruess and Wali 1980; Richardson 1982).

Atriplex triangularis Willd., an annual halophyte, grows successfully in soils with salinity levels approaching sea water (Riehl and Ungar 1983; Ungar 1977). Black (1956) studied the ionic relations of A. triangularis, and found a higher concentration of Cl- in the root than in the shoot throughout the range of salinities tested. Root Na+ concentration was also higher in most salinities, suggesting that A. triangularis may hold back the salts in the root. In contrast, Osmond and others (1980) found a lower concentration of these ions in the root than in the shoot. These data agree with the electrophysiological measurements of Anderson and others (1977) and ion probe data of Kramer and others (1978).

The objectives of the present research were to determine the mechanisms by which A. triangularis plants adjust to salt stress. The effect of salinity on the ionic content, water potential, osmotic potential, pressure potential, and succulence of plant organs was determined.

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MATERIALS AND METHODS

Growth

Atriplex triangularis seeds were collected in October 1980 from a salt marsh near Rittman, Ohio, and refrigerated until used. Seeds were sown in Flint-Lock sand in a growth chamber set for a 12-hour day at 25° C and a 12-hour night at 15° C. Four leaf stage seedlings (1.5 to 2.5 cm long) were transferred to plastic quart containers. The exteriors of the containers were painted black and covered with aluminum foil to prevent algal growth. The culture solution used was Hoagland and Arnon #2. Salinity was increased in 0.5 percent NaCl increments every 48 hours, to allow time for acclimation, until desired salinity was attained. Solutions were continuously aerated with air pumps. Nutrients and salts were replaced weekly. Plants were grown in an M13 Environmental Growth Chamber set for a 16-hour day at 25° C and an 8-hour night at 15° C. Light intensity was 1400 foot-candles; relative humidity was 73 percent. All of the experiments were performed on 13-to 15-week-old plants.

Water Relations

Xylem pressure potential was measured with a pressure chamber (Soil Moisture Equipment Corp. Model 3005). The stem was cut close to the root with a sharp razor blade, and the cut end was then fitted through the lid of the chamber. The balancing pressure at which sap appeared at the cut end was recorded as xylem pressure potential. Bubbling that occurred at pressures below 0.1 MPa and commenced with elevated pressure was ignored, as recommended by Phillips (1981). After wiping the cut end clean, a filter paper disk 4 mm in diameter was saturated with expressed sap and used to determine xylem sap osmotic potential. Since it is believed that only the earliest effluxes of sap represent intracellular osmotic potential (Barrs 1968), special effort was made to use only this portion of the sap for the measurements.

Leaf water potential, leaf osmotic potential, and xylem pressure potential were measured with a Wescor HR-33T dew point microvoltmeter. A leaf punch, 4 mm in diameter, was removed. This disk was either homogenized with a glass rod to determine osmotic potential, or left intact to determine water potential. Homogenized leaf tissue, leaf disk, or saturated filter paper disk was sealed promptly in a Wescor C52 sample chamber. Equilibration times were 7 and 30 minutes for osmotic potential and 30 minutes for water potential.

Leaf Age and Salt Bladder

Leaves from the three uppermost nodes were designated as young leaves; leaves from the three lowest nodes were designated as mature leaves. Salt bladders were removed from one group of leaves and these leaves were subsequently rinsed briefly with distilled water and blotted dry before use. In a second group, leaves were briefly rinsed to remove the surface salt prior to use.

Ion Analysis

Fresh tissue samples were weighed and oven dried at 80° C to a constant dry weight. Tissue water content was calculated as the difference between the fresh and dry weight measurements. Dried samples were ashed overnight at 450° C in a Thermolyne 1400 muffle furnace. Ash was dissolved in known amounts of double distilled water and used for analysis. Concentrations of Na^+ and K^+ were determined by flame emission and Mg^{2+} and Ca^{2+} by atomic absorption using a Perkin-Elmer model 360 atomic absorption spectrophotometer. Chloride concentration was estimated with a Beckman specific ion electrode using NaCl as the standard. The intracellular concentration was estimated from tissue water content.

Statistical analysis systems on an IBM 370 computer were used to analyze these data.

RESULTS

Water Relations

Leaf water potential, osmotic potential, and root and stem xylem osmotic potential became more negative as water potential of the culture solution decreased (figs. 1,2,3). These values all

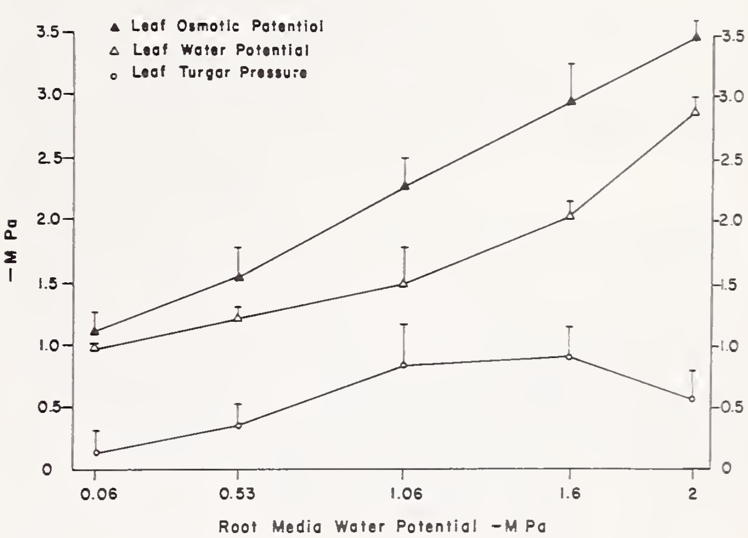

Figure 1.--Water potential (-MPa), osmotic potential (-MPa), and turgor pressure (MPa) for leaves from _Atriplex triangularis_ plants grown in 0.5 strength Hoagland and Arnon No. 2 nutrient solution. Sodium chloride was added to attain media water potential. Data = mean ± S.E.M.

showed significant correlation with media conductivity and remained more negative than the media water potential. Progressive increase in media salinity resulted in more negative root xylem pressure potential. This value was usually less

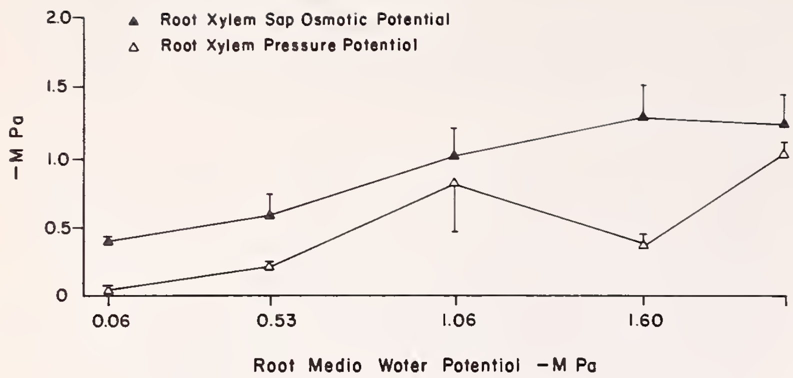

Figure 2.--Xylem pressure potential and xylem osmotic potential for roots of Atriplex triangularis plants grown in 0.5 strength Hoagland and Arnon No. 2 nutrient solution. Sodium chloride was added to attain the desired media water potential. Data = mean $\pm$ S.E.M.

negative than the media water potential, leaf water potential, leaf osmotic potential, and stem xylem pressure potential. Control plants had a root osmotic potential about seven times more negative than the medium, indicating an active ion uptake by these plants. In the two intermediate salinities, root osmotic potential was similar to the bathing solutions but lower values were found in the two highest salinities.

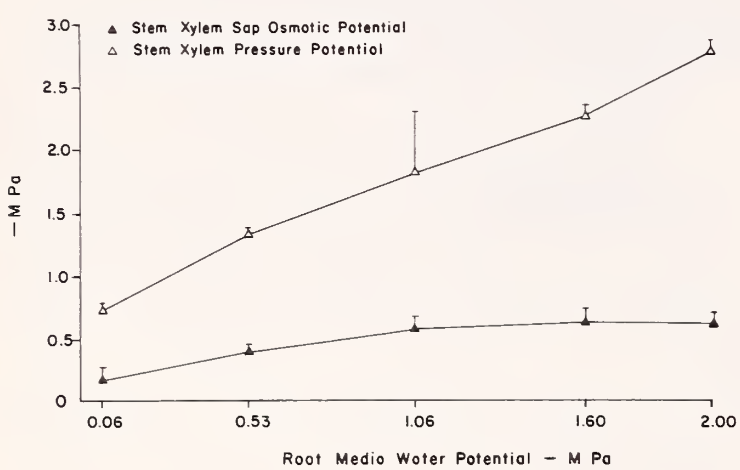

Figure 3.--Xylem pressure potential and xylem sap osmotic potential of shoots from Atriplex triangularis plants grown in 0.5 strength Hoagland and Arnon No. 2 nutrient solution. Sodium chloride was added to attain media water potentials. Data = mean $\pm$ S.E.M.

Shoot xylem pressure potential decreased with the addition of salt up to -1 MPa and then remained unchanged in higher salinities.

The difference between leaf water potential and osmotic potential was calculated as an estimate of leaf pressure potential. This is thought to be more reliable than calculating the difference between xylem pressure potential and leaf osmotic potential since the latter can give false values (Roy and Mooney 1982). Non-saline plants had the lowest leaf pressure potential. While addition of salt to the media improved leaf pressure potential to some extent, the beneficial effect of salt was limited to intermediate salinities. Data for osmotic potential of leaves of different ages is presented in figure 4. Epidermal salt hairs were removed to

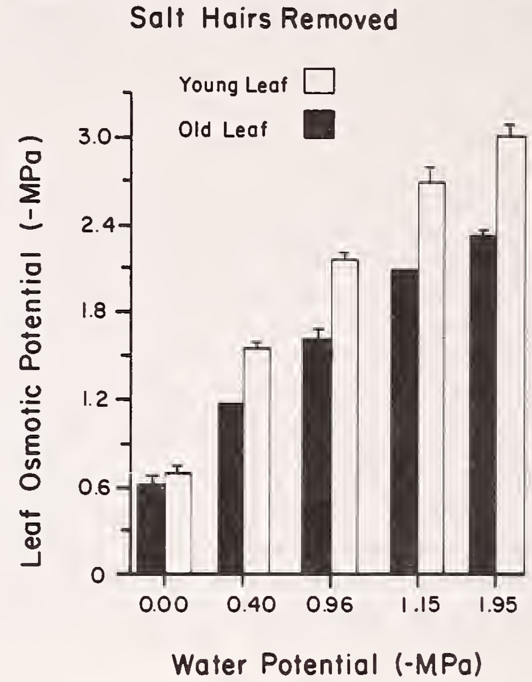

Figure 4.--Osmotic potentials for leaves of Atriplex triangularis with salt hairs removed. Data = mean $\pm$ S.E.M.

avoid the errors that can result from mixing leaf minerals with the ions contained in the bladders. Both young and mature leaves maintained a more negative osmotic potential than external water potential in all treatments. Young leaves maintained a more negative osmotic potential than mature leaves in the range of salinity tested.

Succulence

Leaf succulence was estimated by determining the fresh weight:dry weight ratio. Increase in salinity led to a gradual increase in young leaf succulence. Control plants were least succulent; plants from the highest salinity had the highest succulence (fig. 5). The relationship between salinity and succulence was, however, less direct for mature leaves. Regardless of media salinity, mature leaves from all salt treated plants were more succulent than leaves from control plants. Variation in salinity did not affect succulence. Mature leaves of salt treated plants were consistently more succulent than young leaves.

Correlation Coefficient Between the Components of Water Relation

Results presented in table 1 are helpful in assessing various techniques used to investigate the plants' water status. Both dew point hygrometer and pressure bomb measurements show a significant correlation with media conductivity. Values for xylem pressure potential also demonstrate a correlation with other components. Leaf pressure potential estimates differ from other parameters in that they are not significantly correlated with media conductivity and other components of plant water status.

Table 1.--Correlation coefficient (r) between leaf water potential (Ψ), leaf osmotic potential (π), stem xylem pressure potential (XYPP), stem xylem sap osmotic potential (XYπ), root xylem pressure potential (XYPP), root xylem sap osmotic potential (XYπ), leaf pressure potential (PP), medium water potential (Ψ). P = level of significance.

		Leaf π	Leaf PP	Medium salinity	Stem XYPP	Stem XYπ	Root XYPP	Root XYπ
Leaf Ψ	r	0.88	-0.13	0.87	0.84	0.75	0.71	0.54
	P	0.0001	0.4952	0.0001	0.0001	0.0001	0.0001	0.0048
Leaf π	r		0.36	0.94	0.73	0.71	0.64	0.70
	P		0.0500	0.0010	0.0001	0.0001	0.003	0.0001
Leaf PP	r			0.25	-0.07	0.06	-0.07	0.46
	P			0.1852	0.7300	0.7400	0.7300	0.0177
Medium	r				0.77	0.73	0.69	0.63
Salinity	P				0.0001	0.0001	0.001	0.0006
Stem	r					0.77	0.76	0.55
XYPP	P					0.0001	0.0001	0.0048
Stem XYπ	r						0.66	0.68
	P						0.0001	0.0001
Root XYPP	r							0.49
	P							0.0104

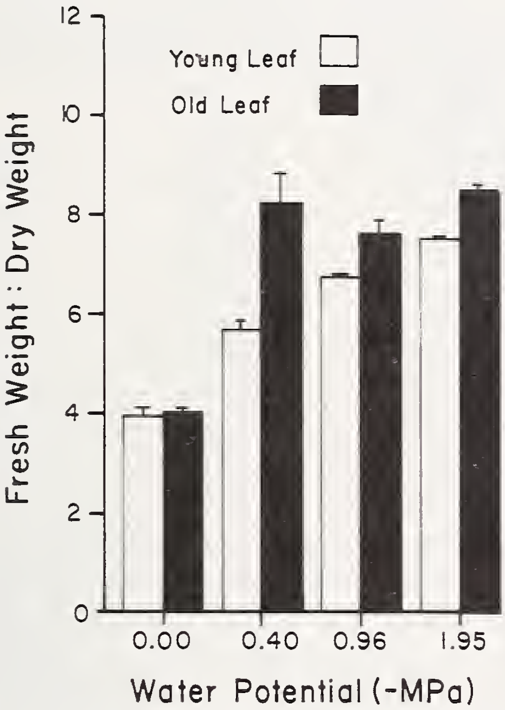

Figure 5.--Fresh weight:dry weight ratios for young and old leaves from Atriplex triangularis plants. Data = mean ± S.E.M. LSD (0.05) for young leaves = 2.5, LSD (0.05) for old leaves = 2.7.

Ion Accumulation

Concentrations of Na+ and Cl-, calculated on dry weight or tissue water content, increased in all organs as a response to a higher concentration of salt in the root media (tables 2,3, and 4). The Cl- content generally increased less than Na+ content. Salt content of mature leaves appeared to be twice as high as that of young leaves when considered on a dry weight basis. However, the concentration of salt in both young and mature leaves was similar. This could be due to the increased succulence of mature leaves that causes a dilution of salt. Young leaves contain more Na+ and Cl- than mature leaves when bladders are intact. This is apparently due to the ions accumulated in these organs, since no difference was observed in leaves of different ages after bladder removal. The difference between the ion content of leaves with and without bladders is expressed as an estimate of ions secreted by the plant (tables 2,3, and 4). This difference is primarily present in young leaves. Removal of the bladders did not affect the ion content of mature leaves. Abscised leaves contained a high concentration of Na+ and Cl-. Concentration of these ions in stems was similar to that in the leaves, but concentrations of Na+ and Cl- in roots were always lower than in the other organs.

Concentrations of K+, Ca^{2+}, and Mg^{2+} showed a similar pattern (tables 5 and 6). Concentrations were highest in the control plants, however, after an initial reduction, ion concentration remained relatively unchanged in response to increased salinity. Young leaves contained more K+, Ca^{2+} and Mg^{2+} than mature leaves. All organs analyzed had a higher concentration of Mg^{2+} than Ca^{2+}. The ratio of K+:Na+ decreased with an increase in medium salinity, from root to shoot, and with leaf aging. Older leaves had higher Na+ and Cl- concentrations than young leaves (tables 6 and 7).

DISCUSSION

A. triangularis responded to increasing media salinity by lowering the leaf water potential, leaf osmotic potential, and stem xylem pressure potential. Similar results were obtained under field conditions by Ungar (1977) in A. triangularis

Table 2.--Concentration of Na+ (meq L^{-1}) present in various organs of Atriplex triangularis grown in 0.5 strength Hoagland and Arnon No. 2 nutrient solution to which NaCl was added to obtain desired salinity. Data = mean ± S.E.M. Young and mature leaves were analyzed with either bladders intact (A) or removed (B). C = A-B is an estimate of Na+ in bladders; LSD = least significant difference.

NaCl (meq L^{-1})		Young leaf	Mature leaf	Abscised leaf	Stem	Root
0	A	95±28	39±8	120±2.5	7.1±1.3	28±4
	B	59±15	41±1	---	---	---
	C	36	2	---	---	---
86	A	400±37	353±71	958±66	519±157	113±26
	B	342±28	381±39	---	---	---
	C	58	---	---	---	---
258	A	811±102	547±49	2347±1275	523±21	338±15
	B	469±50	469±34	---	---	---
	C	342	78	---	---	---
517	A	1001±121	792±22	1893±568	781±75	411±74
	B	691±88	809±55	---	---	---
	C	310	---	---	---	---
LSD (0.05)	B	282	146	2279	285	300

Table 3.--Concentration of CL- (meq L^{-1}) present in various organs of Atriplex triangularis grown in 0.5 strength Hoagland and Arnon No. 2 nutrient solution to which NaCl was added to obtain desired salinity. Data = mean ± S.E.M. Young and mature leaves were analyzed with bladders intact (A) or removed (B). C = A-B is an estimate of Cl- in bladders; LSD = least significant difference.

NaCl (meq L^{-1})		Young leaf	Mature leaf	Abscised leaf	Stem	Root
0	A	37±6	15±1	74±54	43±10	14±2
	B	30±7	14±1	---	---	---
	C	4	1	---	---	---
86	A	217±16	172±6	235±45	160±60	135±42
	B	183±28	215±26	---	---	---
	C	24	---	---	---	---
258	A	705±84	565±71	1306±588	466±33	224±45
	B	287±14	275±27	---	---	---
	C	428	290	---	---	---
517	A	937±113	631±22	1907±775	652±77	249±44
	B	705±99	679±88	---	---	---
	C	232	---	---	---	---
LSD (0.05)	B	240	122	1590	169	93

and by De Jong (1981) in A. leucophylla (Moq) Dietr. A negative shoot water potential relative to media salinity reflects the plant's ability to sustain a water potential gradient which assures the inward flow of water in diverse saline environments. This is achieved by mineral absorption and accumulation of organic compounds (Richardson and McKell 1980; Ruess and Wali 1980; Storey and Wyn Jones 1979). Atriplex triangularis maintains a relatively constant water potential gradient, about -1 to -1.5 MPa, more negative than the external solution. Halophytes adjusting their osmotic potential in this manner are commonly known as osmoconformers (Jefferies 1980; and Wyn Jones 1981).

Negative leaf osmotic potential found in control plants is similar to that found by Kaplan and Gale (1972) in A. halimus L. This is perhaps due to the higher concentrations of K+, Ca^{2+}, Mg^{2+} and oxalate, as reported by Osmond (1966). Leaf pressure potential was higher at intermediate salinities, possibly as a result of improved water balance with increased leaf ionic content. This agrees with Kaplan and Gale (1972) who found a higher leaf pressure potential in salt treated A. halimus.

In the past, several workers have experienced difficulty estimating the water potential of halophytes, when using the dew point technique, because of dissolving salt either from the salt

Table 4.--Concentration of K+ (meq L^{-1}) and ratio of K+/Na+ in various organs of Atriplex triangularis grown in 0.5 strength Hoagland and Arnon No. 2 nutrient solution to which NaCl was added to obtain desired salinity. Data = mean ± S.E.M. LSD = least significant difference.

NaCl (meq L^{-1})		Young leaf	Mature leaf	Stem	Root
0	K+	290±136	171±72	21.2±7	695±182
	K+/Na+	6.1±3.8	3.9±1.37	3.49±1.666	6±0.003
86	K+	82±2	33±8	59±8	103±20
	K+/Na+	0.21±0.017	0.09±0.005	0.13±0.033	1±0.071
258	K+	81±9	36±3	51±4	110±12
	K+/Na+	0.10±0.005	0.07±0.002	0.10±0.005	0.7±0.510
517	K+	36±5	30±3	19±3	49±4
	K+/Na+	0.04±0.005	0.04±0.003	0.02±0.002	0.1±0.027
LSD (0.05)	K+	200	119	9	42
LSD (0.05)	K+/Na+	5.6	2.3	2.7	1.2

Table 5.--Concentration of Ca++ and Mg++ (meq L^{-1}) present in various organs of Atriplex triangularis grown in 0.5 strength Hoagland and Arnon No. 2 nutrient solution to which NaCl was added to obtain desired salinity. Data = mean ± S.E.M. LSD = least significant difference.

NaCl (meq L^{-1})		Young leaf	Mature leaf	Stem	Root
0	Ca++	11.0±5.3	4.3±0.8	2.0±0.3	10.5±1.0
	Mg++	151.9±125.6	15.0±7.4	6.1±1.0	26.6±2.6
86	Ca++	2.0±0.5	1.1±0.7	0.4±0.1	4.6±1.2
	Mg++	6.8±1.9	3.5±1.8	3.5±2.1	7.3±6.1
258	Ca++	4.7±0.7	2.8±0.3	1.4±0.7	3.7±0.7
	Mg++	21.6±3.8	6.9±0.8	5.3±1.5	19.7±2.3
517	Ca++	4.6±0.7	2.1±0.1	3.4±1.3	5.8±0.6
	Mg++	10.5±1.0	7.1±1.3	8.4±1.5	11.1±9.4
LSD (0.05)	Ca++	8.0	1.9	2.4	2.4
LSD (0.05)	Mg++	144.4	12.3	5.1	22.2

excreting structures or discrete salt accumulating cells (Gale and Poljakoff-Mayber 1970). However the present study shows that the removal of bladders and subsequent rinsing of A. triangularis leaves are sufficient for obtaining accurate estimates of osmotic potential and water potential. A high degree of correlation observed between leaf osmotic potential and leaf water potential with stem xylem pressure potential suggests that both measurements are reliable indicators of plant water status. These data should facilitate further water relation studies of A. triangularis.

Root xylem pressure potential was used as an indirect estimate of xylem sap ion concentration, and there was a rather distinct pattern in response to varying media salinity. Root xylem pressure potential of control plants was nearly seven times higher than the external media, similar to the media in intermediate salinities, and less negative than the media in the highest two salinities. This may suggest that plants exert some control over the inward movement of ions at higher salinities, which seems to agree with the flux studies of Anderson and others (1977). They found that the concentration of Na+ was lower in A. triangularis root cells than in the external solution. This has raised the possibility that the permeability of A. triangularis root to Na+ is low and the Na+ that enters the root by passive diffusion is probably removed by active efflux. Kramer and others (1978) employing electron probe microanalysis technique, also found a low concentration of Na+ in the root of A. triangularis at 300 and 600 mM NaCl external solution (comparable with our treatment). This is an additional indication of a possible control over the inflow of Na+ at higher salinities. Kramer and others (1978) found that transfer cells developed in the root epidermis of A. hastata (triangularis) in response to salt treatment. They concluded that these cells excluded Cl- relative to media concentrations. Root ion regulation has been reported in A. canescens (Pursh) Nutt. (Richardson 1982) and A. falcata (M. E. Jones) Standley (Breckle 1974). This strategy may prove to be more widespread in Atriplex species than has been realized.

Salt hairs were restricted to young leaves and seem to serve the purpose of active salt excretion. Limitation of excreting organs to young

Table 6.--Concentration of Na+ and Cl- in *Atriplex triangularis* leaves expressed on a tissue water or dry weight bases. Data = mean ± S.E.M. LSD = least significant difference.

NaCl (meq L^{-1})	Ions	meq L^{-1}		μeq g^{-1} dry weight	
		Young leaves	Mature leaves	Young leaves	Mature leaves
0	Na+	32±2	41±4	150±13	454±101
	Cl-	30±7	15±12	140±36	155±22
86	Na+	343±28	381±39	2033±216	4401±568
	Cl-	183±28	215±26	1080±169	2522±451
258	Na+	469±50	469±37	2627±195	5553±733
	Cl-	287±14	275±30	1631±184	3194±204
517	Na+	691±88	809±55	3666±577	7425±676
	Cl-	705±99	679±88	3752±661	6236±876
LSD (0.05)	Na+	282	146	1670	2306
LSD (0.05)	Cl-	240	122	1398	1127

Table 7.--Summary of analysis of variance for Na+, K+, K+/Na+ ratio, Cl^-, Ca++ and Mg++ in *Atriplex triangularis* organs. All of the ion concentrations are based on tissue water content.

Dependent variable	SS	F	P	LSD
Na+ (meq L^{-1})	9210363.37	6.21	0.0013	57
K+ (meq L^{-1})	259339.30	8.62	0.0001	82
K+/Na+ Ratio	47.40	21.84	0.0001	
Cl- (meq L^{-1})	7911664.29	11.29	0.0001	393
Ca++ (meq L^{-})	1019.15	4.48	0.0078	7
Mg++ (meq L^{-1})	33998.14	3.69	0.0184	45
Leaf succulence	22.55	9.26	0.0058	

leaves is not uncommon. Salt glands of *Avicennia marina* (Forsskal) Vierh. are reported to collapse as leaves age (Drenan and Berjak 1982). Mature leaves of *A. triangularis* use succulence as an alternative to bladders for internal adjustment of ions. A correlation between the reduction in Cl- content of bladder cells and leaf thickening has been reported for many *Atriplex* species (Osmond and others 1980).

A continuous higher concentration of Na+ and Cl- in leaves relative to the root media is an indication of the significant role that these minerals play in plant osmoregulation as found by Black (1960) and Delane and others (1982). The lower concentration of Cl- found in plant leaves in comparison with Na+ is in agreement with the other reports in the literature (Osmond 1966; Kramer and others 1978; Storey and Wyn Jones 1979). It has been proposed that oxalate is synthesized in *Atriplex* leaves in response to excess cations (Osmond 1967).

Expressed stem xylem sap had a less negative osmotic potential than the root osmotic potential, which is an indication of lower concentration of ions in the sap. This could be explained by the very efficient transport and active removal of Cl- ions from the root of *A. triangularis* (Anderson and others 1977). Concentrations of Na+ and Cl- were closely linked to media salinity. This is similar to findings of others (Black 1956; Greenway and others 1966; and Osmond and others 1980).

Concentration of Na+ and Cl- was lower in *Atriplex* roots than in shoots. This differs from results of Black (1956), but agrees with findings of Osmond and others (1980) and Greenway and others (1966). Thus, if there exists a mechanism for control of ion movement from the root to the shoot, these ions are unlikely to be stored in the root. Low concentration of Na+ has been found in the root of a number of *Atriplex* species growing in saline media (Osmond and others 1980; Greenway 1968).

Concentrations of less abundant nutrients, K+, Ca^2+, Mg^2+, are adversely affected by the presence of NaCl in the media, however, after the initial reduction in these ions, their level of absorption is maintained despite the increase in NaCl concentration. A similar reduction in K+ uptake in response to external salinity was reported by Black (1956) and Greenway and others (1966). Black (1956) attributed the high concentration of K+ in *Atriplex* leaves growing in nonsaline media to a luxury uptake by the plant. This additional K+ substitutes for Na+, which is low in the nonsaline media, and is thought to function as an osmoregulator rather than a nutrient. Negative osmotic potential of leaves in the nonsaline medium could be explained on this basis. Concentration of K+ is not reduced beyond a certain level since K+ is essential for the healthy function of cytoplasm (Osmond and others 1980). Presence of NaCl is also linked to the reduced absorption of divalent cations in halophytes. Osmond (1966)

attributed the low concentration of Ca^{2+} in Atriplex species to high concentrations of Na^+ which depressed the Ca^{2} uptake.

One of the interesting features of leaf aging was that mature leaves always maintained lower concentrations of K^+, Ca^{2+} and Mg^{2+} than young leaves, whereas no such difference was observed for Na^+ and Cl^-. Removal of these essential ions from the mature leaves occurred prior to abscission. This, along with high concentrations of Na^+ and Cl^- in abscised leaves, raises the possibility that essential nutrients were withdrawn from mature leaves while Na^+ and Cl^- were left to be removed as leaves eventually abscised. Comparing the green and senescent leaves of a number of halophytes, Karmarkar (1982) reached a similar conclusion. While the senesced leaves contained higher Na^+ and Cl^-, concentrations of K^+, Mg^{2+}, and P were lower than in green leaves. Albert (1974) studied a number of halophytes and found a gradual rise in leaf salt content while nutrients like N, P, and K^+ were translocated into the growing young leaves. Greenway and others (1966) and Yeo (1981), using tracers, confirmed the immobility of salts in the mature leaves of halophytes. This is more significant when considering the apparent adverse effect of Na^+ on the absorption of these nutrients.

The present study appears to suggest that *A. triangularis* contains several mechanisms for mineral regulation which, when used together, enable the plant to avoid potentially harmful concentrations of salt in its tissues. These mechanisms include: salt hairs which remove excess ions from young leaves; succulence which dilutes the ion content of leaf cells; abscission which removes organs containing high salt concentrations; and root ion flux regulation which apparently operates at high salinities. In spite of seemingly effective strategies that work in conjunction for ion regulation, plants accumulate considerable amounts of minerals. These minerals are likely to play a central role in the process of plant osmoregulation.

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PUBLICATIONS CITED

Albert, R. Salt regulation in halophytes. Oecologia. 21: 57-71; 1974.

Anderson, W. P.; Willcocks, D. A.; Wright, B. J. Electrophysiological measurements on the root of *Atriplex hastata*. J. Exp. Bot. 28: 894-901; 1977.

Ashby, W. C., Beadle, N. C. W. Studies on halophytes III. Salinity factors in the growth of Australian saltbush. Ecology. 38: 344-352; 1957.

Black, R. F. Effect of NaCl in water culture on the ion uptake and growth of *Atriplex hastata* L. Aust. J. Biol. Sci. 9: 67-80; 1956.

Black, R. F. Effect of NaCl on the ion uptake and growth of *Atriplex vesicaria* Heward. Aust. J. Biol. Sci. 13: 249-267; 1960.

Breckle, S. W. Wasser-und salzverhaltnisse bei halophytender salzsteppe in Utah/U S A. Ber. Deutsch. Bot. Ges. Bd. 87: 589-600; 1974.

Caldwell, M. M. Physiology of desert halophytes. In: Reimold, R. J.; Queen, W. h., eds. Ecology of halophytes. New York and London: Academic Press; 1974: 355-378.

De Jong, T. M. Water and salinity relations of California beach species. J. Ecol. 69: 647-663; 1981.

Delane, R.; Greenway, H.; Munns, R.; Gibbs, J. Ion concentration and carbohydrate status of the elongating leaf tissue of *Hordeum vulgare* growing at high external NaCl. J. Exp. Bot. 33: 557-573; 1982.

Drenan, P. M.; Berjak, P. Degeneration of the salt glands accompanying foliar maturation in *Avicennia marina* (Forsskal) Vierh. New Phytol. 90: 165-176; 1982.

Flowers, T. J.; Troke, P. F.; Yeo, A. R. The mechanism of salt tolerance in halophytes. Annu. Rev. Plant Physiol. 28: 89-121; 1977.

Gale, J.; Poljakoff-Mayber, A. Interrelation between growth and photosynthesis of saltbush (*Atriplex halimus*) grown in saline media. Aust. J. Biol. Sci. 23: 937-945; 1970.

Greenway, H.; Gunn, A.; Thomas, D. A. Plant response to saline substrates VIII. Regulation of ion concentration in salt-sensitive and halophytic species. Aust. J. Biol. Sci. 19: 741-756; 1966.

Jefferies, R. L. The role of organic solutes in osmoregulation in halophytic higher plants. In: Rains, D. W.; Valentine, R. C.; Hollander, A., eds. Genetic engineering of osmoregulation. New York: Plenum Publishing; 1980: 135-153.

Kaplan, A.; Gale, J. Effect of sodium chloride salinity on water balance of *Atriplex halimus*. Aust. J. Biol. Sci. 25: 985-1003; 1972.

Karmarkar, S. M. Senescence in mangroves. In: Sen, D. N.; Rajpurchit, K. S., eds. Contribution to the ecology of halophytes. The Hague: Dr. W. Junk Publishers; 1982: 173-187.

Kramer, D.; Anderson, W. P.; Preston, J. Transfer cells in the root epidermis of Atriplex triangularis L. as a response to salinity: a comparative cytological and X-ray microprobe investigation. Aust. J. Biol. Sci. 5: 739-747; 1978.

Liphschitz, N.; Waisel , Y. Adaptation of plants to saline environments: salt excretion and glandular structures. In: Sen, D. N.; Rajpurohit, K. S., eds. Contribution to the ecology of halophytes. The Hague: Dr. Junk Publishers; 1982: 173-187.

Osmond, C. B. Divalent cation absorption and interaction in Atriplex. Aust. J. Biol. Sci. 19: 37-48; 1966.

Osmond, C. B. Acid metabolism in Atriplex. I Regulation of ion synthesis by the apparent excess cation absorption in leaf tissue. Aust. J. Biol. Sci. 20: 575-587; 1967.

Osmond, C. B.; Bjorkman, O.; Anderson, D. J. Physiological processes in plant ecology. Berlin: Springer-Verlag; 1980: 468.

Phillips, D. L. End-point recognition in pressure chamber measurements of water potential of Viguiera porteri (Asteraceae). Ann. Bot. 48: 905-907; 1981.

Richardson, S. G. High and low sodium biotypes of fourwing saltbush: their responses to sodium and potassium in retorted oil shale. J. Range Manage. 35: 795-797; 1982.

Richardson, S. G.; McKell, C. M. Water relation of Atriplex canescens as affected by the salinity and moisture percentage of processed oil shale. Agron. J. 72: 946-952; 1980.

Riehl, T. E.; Ungar, I. A. Growth, water potential and ion accumulation in the inland halophyte Atriplex triangularis under saline field conditions. Oecol. Plant. 4: 27-39; 1983.

Roy, J.; Mooney, H. A. Physiological adaptation and plasticity to water stress of coastal and desert populations of Heliotropium currassavicum L. Oecologia. 52: 370-375; 1982.

Ruess, R. W.; Wali, M. K. Daily fluctuation in water potential and associated water changes in Atriplex canescens. Oecologia. 47: 200-203; 1980.

Schirmer, U.; Breckle, S. W. The role of bladders for salt removal in some Chenopodiaceae (mainly Atriplex species). In: Sen, D. N.; Rajpurohit, K. S., eds. Contribution to the ecology of halophytes. The Hague: Dr. W. Junk Publishers; 1982: 215-231.

Sharma, M. L. Aspects of salinity and water relation of Australian Chenopods. In: Sen, D. N.; Rajpurahit, K. S., eds. Contribution to the ecology of halophytes. The Hague: Dr. W. Junk Publishers; 1982: 155-172.

Scholander, R. F.; Bradstreet, E. D.; Hammel, H. T.; Hemmingsen, E. A. Sap concentration in halophytes and some other plants. Plant Physiol. 41: 529-532; 1966.

Storey, R.; Wyn Jones, R. J. Responses of Atriplex spongiosa and Suaeda monoica to salinity. Plant Physiol. 63: 156-162; 1979.

Ungar, I. A. The relationship between the soil water potential and plant water potential in two inland halophytes under field conditions. Bot. Gaz. 138: 498-591; 1977.

Waisel, Y. Biology of halophytes. New York: Academic Press; 1972: 395.

Wood, J. G. The selective absorption of chlorine ions; and the absorption of water by the leaves in the genus Atriplex. Aust. J. Exp. Biol. Med. Sci. 2: 45-56; 1937.

Wyn Jones, R. J. Salt tolerance In: Johnson, C. B., ed. Physiological processes limiting plant productivity. London: Butterworths; 1981: 271-292.

Yeo, A. R. Salt tolerance in the halophyte Suaeda maritima L. Dum: Intercellular compartmentation of ions. J. Exp. Bot. 32: 487-497; 1981.

In: Tiedemann, Arthur R.; McArthur, E. Durant; Stutz, Howard C.; Stevens, Richard; Johnson, Kendall L., compilers. Proceedings--symposium on the biology of Atriplex and related chenopods; 1983 May 2-6; Provo, UT. General Technical Report INT-172. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 309 p.

SEASONAL LEAF NITRATE REDUCTASE ACTIVITY, NITROGEN AND NITRATE CONTENT, AND WATER RELATIONS OF *ATRIPLEX CANESCENS* IN THE NORTHERN CHIHUAHUAN DESERT

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ABSTRACT: Seasonal nitrate reductase (NR) activity of young, uppermost leaves of *Atriplex canescens* (Pursh) Nutt. (diploid genotype) growing *in situ* was maximal during reproductive growth. Because precipitation on the study site coincided with reproductive growth, higher NR activity during this period may have been due to new leaf growth and increased soil NO_3^- availability rather than the nitrogen sink in developing seeds. Seasonal leaf water content (percent) was significantly ($P<0.10$) correlated with NR activity. Stem xylem water potentials were not correlated with NR activity. Although thermal adaptation of NR would, in general, be advantageous for plants inhabiting a desert environment with widely fluctuating seasonal temperatures, there was no evidence to suggest that acclimation of NR occurs in *A. canescens* growing *in situ*.

INTRODUCTION

Perennial plants inhabiting the northern Chihuahuan desert are exposed to extended periods of drought, wide fluctuations in seasonal temperatures, and high solar insolation. These factors are intimately involved in regulating nitrate reductase (NR) activity. High temperatures rapidly inactivate NR (Onweunne and others 1971; Mattas and Pauli 1965), and water stress depresses NR activity through reduced synthesis of the enzyme (Morilla and others 1973). Irradiation is involved in both the synthesis (Hagemen and Flesher 1960) and maintenance (Klepper and others 1971) of NR. Of particular importance in a desert environment is the availability of soil NO_3^-, and its uptake and translocation to NR sites in canopy leaves. Since NR induction occurs in the presence of NO_3^-, the seasonal balance between leaf NR activity and NO_3^- levels may be critical in establishing reduced nitrogen concentrations of *Atriplex canescens* (Pursh) Nutt. plants during prolonged dry periods *in situ*. Optimal NR activity may occur only during a rather brief period following rainfall when new leaf growth is initiated and when more optimal soil- and plant-water relations permit increased leaf NO_3^- levels for NR induction.

Harmer and Lee (1981) suggested that NR acclimates to low temperatures. It was not, however, evident whether their data support acclimation or, instead, an inhibition of NR under the colder growing temperature, thus leading to NO_3^- accumulation. The initial objective of the present study was to determine if NR is capable of thermal adaptation in *A. canescens* growing *in situ*. The second objective was to determine the seasonal NR activity, NO_3^- content, and reduced nitrogen levels of *A. canescens* growing *in situ* relative to leaf-water relations. A substantial increase in NR activity has been observed during the post-flowering reproductive growth period in *Phaseolus vulgaris* L. (Franco and others 1979) and a decline in NR activity occurred throughout a comparable period in *Glycine max* L. (Franco 1977; Harper and Hageman 1972) where there was no water stress. The final objective was to examine NR activity during reproductive growth *in situ* where soil water is often limited.

METHODS

Leaf samples (ca. 5 grams) from mature fourwing saltbush (*Atriplex canescens* [Pursh] Nutt.) plants growing *in situ* near Las Cruces, N. Mex. (diploid [2n=18] ca. 32° 37' N 106° 45' W were collected at approximately 25 day intervals from August 1981 through November 1982 for NR activity assays and nitrogen and NO_3^- content determinations. All samples were collected within 1.5 hours prior to solar noon except for September 25 and 26, 1981, when samples were collected prior to sunrise, at approximately solar noon, and 4.5 hours after solar noon. Sample collection days were cloudless except for the partly cloudy day of September 11, 1981. Young, fully expanded leaves located on the south side and top of the plant canopy were collected for subsequent analyses. The same four to six plants were used throughout the study period. The samples were transported to the laboratory in the dark at 32° F (0° C) for immediate NR activity analysis. Leaf water content was determined on three subsamples by drying the tissue for approximately 24 hours at 176° F (80° C). The dried samples were stored for subsequent determinations of nitrogen and NO_3^- content. Stem xylem pressure potentials were measured with a PMS pressure bomb. Precipitation received during the study period and ambient air temperatures were compiled from a U.S. Weather Bureau station located within 33 feet (10 meters) of the study site. NR activity and NO_3^- content were determined on three subsamples of leaf material from the field samples. Total

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leaf nitrogen was determined on three subsamples of a composite sample. To assay in vitro NR activity, leaf material (ca. 0.5 grams fresh weight per sample) was ground cold in a mortar with 5 ml extraction medium and 3 grams washed quartz sand. The grinding medium consisted of 25 mM K_2HPO_4 at pH 7.5, 5 mM EDTA·Na_2, 10 mM 2-mercaptoethanol and 3 percent (W/V) BSA, the last added to stabilize enzyme activity (Schrader and others 1974). After centrifugation at 30 000 g for 15 minutes, the supernatant crude extract was assayed for NR activity within 1 hour. The assay procedure was essentially that of Hageman and Hucklesby (1971), with the zinc acetate/phenazine methosulfate modification of Scholl and others (1974).

Oven dried leaf material was ground to 40-mesh for determination of nitrogen and NO_3^- content. Two tissue samples from each of the subsamples were digested (block digestor) for nitrogen determinations with 20:1 H_2SO_4:H_3PO_4 in the presence of 200:1 K_2SO_4:Se catalyst mixture. Nitrogen content was determined from an aliquot of the diluted digest, using the colorimetric method involving the reaction of ammonium with sodium salicylate, sodium nitroprusside, and sodium hypochlorite with absorption readings at 660 nm (Technicon Industrial Systems, Industrial Method No. 334-74W/B^+, 1977). Nitrogen content was calculated using standard NH_4Cl concentrations carried through the digestion and colorimetric procedure. Nitrate content was determined by the method of Cataldo and others (1975).

RESULTS

Diurnal NO_3^- Levels and NR Activity

Maximum NR activity occurred at solar noon and minimal activity occurred 4.5 h after solar noon (table 1). Leaf NO_3^- levels were highest prior to sunrise. These data suggest a diurnal NR activity rhythm, a pattern consistent with other findings (Bowerman and Goodman 1971; Lewis and others 1982). Diurnal NR activity and residual NO_3^- levels indicate considerable NO_3^- was translocated into the leaf tissue during the photoperiod.

Seasonal NR Activity

Maximum leaf NR activity occurred during the initial sampling date of August 1981 (fig. 1A). At this time, mature fruits were present on the plants sampled, although a large proportion of the fruits had already abscised. NR activity decreased after this initial sampling date to a reasonably stable rate (approximately 6 µmol $NO_2^-\cdot gDW^{-1}\cdot h^{-1}$) that persisted through the winter to early June. Increased NR activity occurred in mid-June and coincided with the onset of reproductive growth and summer rainfall (fig. 1D). This increase in NR activity continued throughout the reproductive growth period (June through November). Mature fruits were abscising

Table 1.--Diurnal in vitro leaf nitrate reductase (NR) activity and NO_3^--N levels within the uppermost, young leaves of *Atriplex canescens* (Pursh) Nutt. growing in situ on September 25 (approximately solar noon) and September 26 (prior to sunrise and approximately 4.5 hours after solar noon), 1981. Values in parentheses represent ± 1 standard error of the means.

	Before sunrise	Solar noon	4.5 hrs past noon
NR activity			
(µmol $NO_2^-\cdot gDW^{-1}\cdot h^{-1}$)	4.71	8.61	2.95
	(1.68)	(2.29)	(1.40)
NO_3^--N			
(mg $NO_3^-N\cdot gDW^{-1}$)	0.94	0.76	0.77
	(0.01)	(0.15)	(0.05)

during the last sampling date of November 3, 1982. The high NR activity found during the initial sampling date in August 1981, was not evident during reproductive growth in 1982. NR activity has been shown to fluctuate in response to leaf water status in several plants (Beevers and Hageman 1980), and in *A. confertifolia* irrigated with various levels of NaCl (Kleinkopf 1975). In the present study, activity of NR and leaf water content (fig. 1C) followed similar seasonal trends and were significantly correlated ($P<0.05$; $r=0.47$). Seasonal xylem water potentials of the terminal portion (4 to 6 inches/10 to 15 cm) of stems bearing leaves representative of those assayed for NR activity were not, however, significantly correlated ($P<0.10$) with leaf NR activity.

Maximum NO_3^- levels (fig. 1A) coincided with minimal NR activity (fig. 1A) and low leaf water content (fig. 1C) during the winter. Similar increases in leaf NO_3^- concentrations have been associated with the inhibition of NR activity by leaf water stress resulting in an accumulation of the NR substrate, NO_3^- (Plaut 1973; Srivastava 1980). Leaf NO_3^- levels and NR activity followed similar trends for the remainder of the study. Precipitation during the latter period (fig. 1D) would tend to enhance root growth, and thus NO_3^- uptake and its translocation to leaves. Similarly, more favorable soil water relations following precipitation would enhance leaf water relations (fig. 1C) for efficient NO_3^- reduction by NR (Kleinkopf and others 1975). Total reduced nitrogen varied between 38 (May 1982) and 25 mg N·gDW^{-1} (November 1982) (fig. 1B).

Leaf N content declined 35 percent during the initial 7-month period when leaf water content and NR activity substantially declined. Thereafter, a discernible seasonal trend in nitrogen levels was not evident.

The potential for thermal adaptation of NR to seasonal fluctuations in ambient temperature (fig. 1D) was determined on leaf samples collected from October 1981 through October 1982 (fig. 2). Maximum NR activity occurred at approximately 86° to 95° F (30° to 35° C) assay temperature, regardless of the sampling date. NR activity at 86° to 95° F (30° and 35° C) differed significantly ($P<0.05$; NR activity at 86° F > 95° F; 30° C > 35° C) only on July 22, 1982. Therefore, the ability of NR to acclimate to seasonal ambient temperature fluctuations was not apparent in the present study.

The thermal stability of NR was determined at 5-minute intervals for 20 minutes at 68°, 86°, and 104° F (20°, 30°, and 40° C) to determine if NR activity was stable throughout the incubation period (15 minutes) during routine assays (fig. 2, insert). NR activity remained fairly constant throughout this 20-minute period at 68° and 86° F (20° and 30° C), but decreased approximately 35 percent at 104° F (40° C). Thus, NR activity depicted in figure 2 at 104° and 113° (40° and 45° C) (and perhaps 95° F (35° C)) probably represents nonstable rates and is a function of the rate of thermal inactivation during the incubation period of routine NR activity assays.

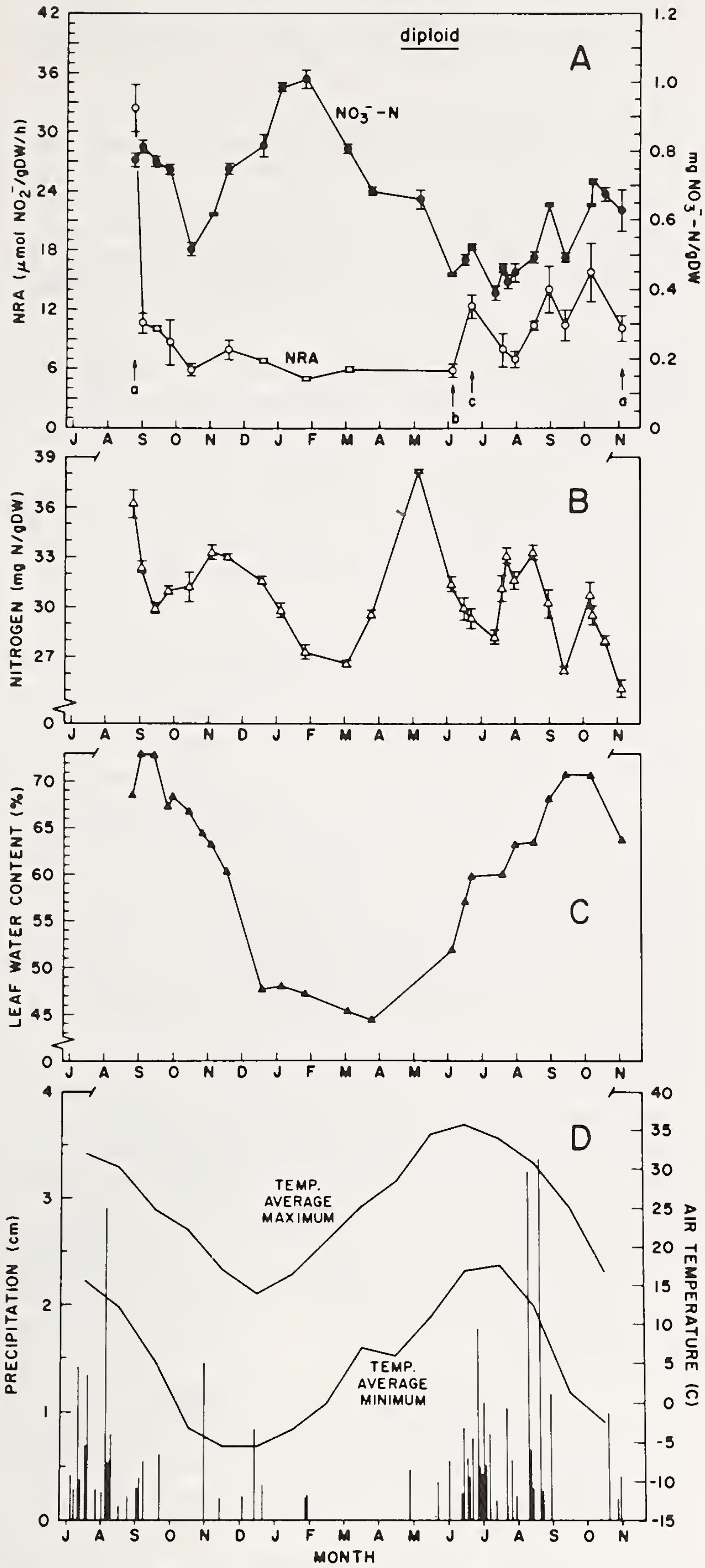

Figure 1.--Seasonal leaf nitrate reductase (NR) activity and leaf NO_3^--N (A), nitrogen (B), and leaf water content (percent) (C) of the diploid genotype of Atriplex canescens (Pursh) Nutt. growing in situ. Vertical bars represent ± 1 standard error of the means. Reproductive growth stages are indicated in A by arrows (a - mature fruit present and some fruit abscission; b - first observation of flowering; c - fruit growth initiated). Monthly ambient average high and low temperatures and precipitation (D) approximately 33 feet (10 meters) from the study site from August 1981 through October 1982.

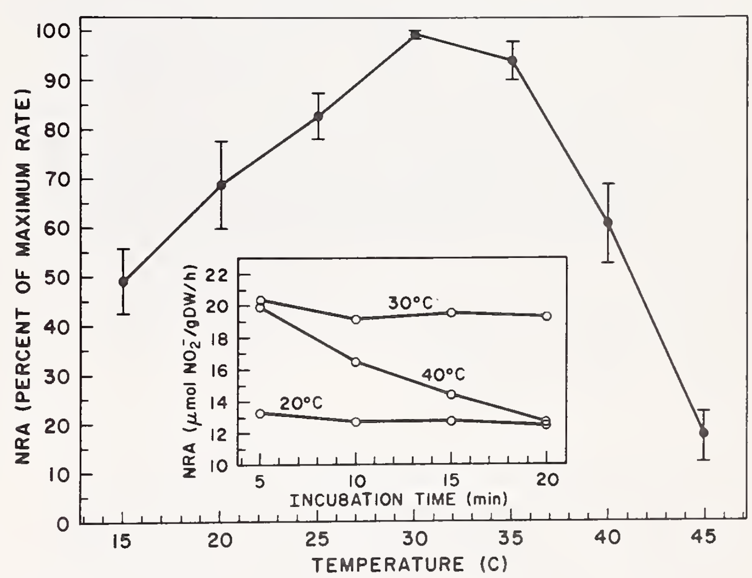

Figure 2.--Nitrate reductase (NR) activity response to temperature 59° to 113° F; 15° to 45° C) for Atriplex canescens (Pursh) Nutt. growing in situ from October 1981 through October 1982. Data from all analyses (10/20/81, 11/3/81, 1/14/82, 3/24/82, 5/6/82, 6/15/82, 7/22/82 and 10/8/82) were combined and are shown. Vertical bars represent 95 percent confidence intervals. Thermal stability of NR activity within the young, uppermost leaves during October 19, 1982, at 68°, 86°, and 104° F (20°, 30°, and 40° C) is shown in the insert.

DISCUSSION

Throughout this study, an attempt was made to collect random, but uniformly young, leaves from the south side and top of plant canopies. Therefore, it would be reasonable to assume that seasonal leaf samples were not representative of a single age group or include sequentially older leaves as the study progressed. The age composition of the leaves present, and hence leaf samples collected, varied throughout the year in response to leaf aging, abscission, and the initiation of new leaf growth. Thus, results of the present study are representative of the youngest, most physiologically active leaves present at any given time, where nitrogen assimilation primarily occurs (Srivastava 1980).

The effect of leaf age was readily demonstrated on August 25, 1981, when the older leaves of plants growing *in situ* possessed NR activity equivalent to 3 percent of that of younger leaves. Leaf water content of the older leaves was approximately 6 percent less than that of the younger leaves.

Seasonal leaf NR activity of *A. canescens* growing *in situ* was significantly correlated ($P<0.10$) with leaf water content, consistent with results from other studies (Huffaker and others 1970; Morilla and others 1973; Tischler and others 1978). On a seasonal basis, stem xylem water potentials were not correlated ($P<0.10$) with NR activity. During periods of low NR activity and leaf water content, NO_3^- accumulated in the leaves. Nitrate accumulation and lower NR activity during water stress have been attributed to a decline in the synthesis of NR (Morilla and others 1973). Shaner and Boyer (1976a, b) demonstrated that NR activity recovery after cessation of water stress was dependent upon protein synthesis and correlated with NO_3^- flux into the leaves rather than the leaf NO_3^- content. Thus, the controlling influence of optimal soil water content on NO_3^- availability and uptake, and the need for favorable leaf water content for efficient NR activity within plants growing *in situ*, is evident from the present study and others.

Reproductive growth during the post-flowering period resulted in substantial NR activity increases in *Phaseolus vulgaris* L. (Franco and others 1979). In contrast, a continuous decline in both NR activity and NO_3^- uptake occurred during this same period in soybean (*Glycine max* L.) (Franco 1977; Harper and Hageman 1972). In the present study, reproductive growth by *A. canescens* appeared to have little or no influence on leaf NR activity since low NR activity coincided with flowering (June 4, 1982). Rather, the enhanced levels of NR activity that occurred during reproductive growth were probably due to rainfall on the study site and new leaf growth. Hence, leaf NR activity coincident with reproductive growth of *A. canescens* growing *in situ* appears dependent upon favorable plant and soil water relations. These conditions would enhance soil NO_3^- availability and uptake, its translocation to leaves, and the production of new leaves. The wing-like bracts of the fruits possess the enzyme (2.1 $\mu mol\ NO_2^- \cdot gDW^{-1} \cdot h^{-1}$, September 1982) and thus, the primary site of nitrogen reduction for developing seeds may be within these bracts, independent of leaves.

There was no evidence in the present study suggesting that NR of *A. canescens* growing *in situ* is capable of thermal adaptation to seasonal ambient temperature fluctuations (fig. 2). Maximum NR activity occurred at assay temperatures of 86° to 95° F (30° to 35° C) throughout the year, though monthly average temperatures varied from a maximum of 97° F (36° C) in July to a minimum of 21° F (-6° C) in January. Harmer and Lee (1981) suggested acclimation of NR appeared evident in two grass species because NR activity increased after transferring the plants from a 68° F (20° C) growth temperature to one of 41° F (5° C) for 1 week. However, lack of pertinent associated data such as assay temperature, tissue NO_3^- levels, and particularly NR activity over a range of temperatures tends to obscure an interpretation concerning the occurrence of acclimation. For example, in the present study, NR activity at an assay temperature of 86° F (30° C) was 4.3 $\mu mol\ NO_2^- \cdot gDW^{-1} \cdot h^{-1}$ in October and 9.0 $\mu mol\ NO_2^- \cdot gDW^{-1} \cdot h^{-1}$ during November when ambient average daily temperatures were 59° and 48° F (15° and 9° C), respectively. Although higher NR activity occurred in leaves during the colder month of November, acclimation was not evident because maximum NR activity during both months occurred at 86° F (30° C) when assayed at temperatures between 59° and 113° F (15° and 45° C). As a general phenomenon, thermal acclimation of NR would be adaptive for evergreen plants inhabiting environments with large annual fluctuations in ambient temperature. However, there appears little evidence at the present time that NR is capable of such acclimation.

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PUBLICATIONS CITED

Beevers, L.; Hageman, R. H. Nitrate and nitrite reduction. In: Miflin, B.J., ed. The biochemistry of plants, Vol. 5, Amino acids and derivatives. [New York: Academic Press]; 1980: 116-159.

Bowerman, A.; Goodman, P.J. Variation in nitrate reductase activity in *Lolium*. Ann. Bot. 35: 353-366; 1971.

Cataldo, D.A.; Haroon, M.; Schrader, L.E.; Youngs, V.L. Rapid colorometric determination of nitrate in plant tissue by nitration of salicylic acid. Comm. Soil Sci. Plant Anal. 6: 71-80; 1975.

Franco, A.A. Nutritional constraints for tropical grain legume symbiosis. In: Vincent, J.M.; Whitney, A.S.; Bose, J.; eds. Exploiting the legume-rhizobium symbiosis in tropical agriculture; Misc. Publ. 145; College of Tropical Agriculture, University of Hawaii, Honolulu, HI. 1977: 237-252.

Franco, A.A.; Pereira, J.C.; Neyra, C.A. Seasonal patterns of nitrate reductase and nitrogenase activities in Phaseolus vulgaris L. Plant Physiol. 63: 421-424; 1979.

Hageman, R.H.; Flesher, D. Nitrate reductase activity in corn seedlings as affected by light and nitrate content of the nutrient media. Plant Physiol. 35: 700-708; 1960.

Hageman, R.H.; Hucklesby, D.P. Nitrate reductase from higher plants. Meth. Enzymol. 23: 491-503; 1971.

Harmer, R.; Lee, J.A. Some effects of temperature on nitrate reductase in upland and lowland populations of pasture grasses. Plant Sci. Lett. 21: 295-303; 1981.

Harper, J.E.; Hageman, R.H. Canopy and seasonal profiles of nitrate reductase in soybeans (Gycine max L. Merr.). Plant Physiol. 49: 146-154; 1972.

Huffaker, R.C.; Radin, T.; Kleinkopf, C.E.; Cox, E.L. Effects of mild water stress on enzymes of nitrate assimilation and of the carboxylative phase of photosynthesis in barley. Crop Sci. 10: 471-474; 1970.

Kleinkopf, G.E.; Wallace, A.; Cha, J.W. Sodium relations in desert plants: 4. Some physiological responses of Atriplex confertifolia to different levels of sodium chloride. Soil Sci. 120: 45-48; 1975.

Klepper, B.; Flesher, D.; Hageman, R.H. Generation of reduced nicotinamide adenine dinucleotide for nitrate reduction in green leaves. Plant Physiol. 48: 580-590; 1971.

Lewis, O.A.M.; Watson, E.F.; Hewitt, E.J. Determination of nitrate reductase activity in barley leaves and roots. Ann. Bot. 49: 31-37; 1982.

Mattas, R.E.; Pauli, A.W. Trends in nitrate reduction and nitrogen fractions in young corn (Zea mays L.) plants during heat and moisture stress. Crop Sci. 5: 181-184; 1965.

Morilla, C.A.; Boyer, J.S.; Hageman, R.H. Nitrate reductase activity and polyribosomal content of corn (Zea mays L.) having low water potentials. Plant Physiol. 51: 817-824; 1973.

Onwueme, I.C.; Laude, H.M.; Huffaker, R.C. Nitrate reductase activity in relation to heat stress in barley seedlings. Crop Sci. 11: 195-200; 1971.

Plaut, Z. The effect of soil moisture tension and nitrogen supply on nitrate reduction and accumulation in wheat seedlings. Plant Soil 38: 81-94; 1973.

Scholl, R.L.; Harper, J.E.; Hageman, R.H. Improvements of the nitrate color development in assays of nitrate reductase by phenazine methosulfate and zinc acetate. Plant Physiol. 53: 825-828; 1974.

Schrader, L.E.; Cataldo, D.A.; Peterson, D.M. Use of protein in extraction and stabilization of nitrate reductase. Plant Physiol. 53: 688-690; 1974.

Shaner, D.L.; Boyer, J.S. Nitrate reductase activity in maize (Zea mays L.) leaves. I. Regulation by nitrate flux. Plant Physiol. 58: 499-504; 1976a.

Shaner, D.L.; Boyer, J.S. Nitrate reductase activity in maize (Zea mays L.) leaves. II. Regulation by nitrate flux at low leaf water potential. Plant Physiol. 58: 505-509; 1976b.

Srivastava, H.S. Reglation of nitrate reductase activity in higher plants. Phytochem. 19: 725-733; 1980.

Tischler, C.R.; Parvis, A.C.; Jordan, W.R. Factors involved in in vitro stabilization of nitrate reductase from cotton (Gossypium hirsutum L.) cotyledons. Plant Physiol. 61: 714-717; 1978.

In: Tiedemann, Arthur R.; McArthur, E. Durant; Stutz, Howard C.; Stevens, Richard; Johnson, Kendall L., compilers. Proceedings--symposium on the biology of Atriplex and related chenopods; 1983 May 2-6; Provo, UT. General Technical Report INT-172. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 309 p.

WINTER NUTRITIVE VALUE OF ACCESSIONS OF FOURWING SALTBUSH

(*Atriplex canescens* [Pursh] Nutt.) GROWN IN A UNIFORM GARDEN

Bruce L. Welch and Stephen B. Monsen

ABSTRACT: Winter crude protein and *in vitro* digestibility were determined for the current year's growth of 43 and 31 accessions of fourwing saltbush (*Atriplex canescens* [Pursh] Nutt.) grown in a uniform garden. The crude protein level varied significantly among the accessions from 6.0 to 14.2 percent. *In vitro* digestibility also varied significantly among the accessions from 29.1 percent to 46.9 percent. Productivity varied significantly among the accessions from 197 to 1 451 grams per plant. Genetic factors play an important role in determining crude protein level, digestibility, and productivity in fourwing saltbush. Selection and breeding programs can be designed to capitalize on this genetic variation in developing superior cultivars of fourwing saltbush.

INTRODUCTION

Energy producing compounds and protein are nutrients commonly listed as being deficient in the winter diet of mule deer and livestock (Dietz 1965; Halls 1970; Nagy and Wallmo 1972; Welch and McArthur 1979a). Plants that retain significant amounts of green leaves during the winter usually contain higher levels of nutrients than those that shed their leaves (Ensminger and Olentine 1978; Welch 1983; Welch and others 1983a). There is evidence that individual plants and accessions of fourwing saltbush (*Atriplex canescens* [Pursh] Nutt.) vary in the number of leaves retained during the winter (McArthur and others 1978; McArthur and others 1983). This differential retention of winter leaves among individual plants and accessions of fourwing saltbush is probably associated with differences in winter nutritive value (Welch and others 1983a). Also, McArthur and others (1983) reported significant quality difference among accessions of fourwing saltbush grown in a uniform garden. Welch and Monsen (1981) demonstrated that 43 accessions of fourwing saltbush differed significantly in winter crude protein content. We undertook this study to determine the *in vitro* digestibility of 31 accessions with the highest crude protein. We also estimated the forage production for 41 of the 43 accessions.

MATERIALS AND METHODS

A uniform garden was located about 5 miles (8 km) south of Bliss, Gooding County, Idaho. Prior to planting, the garden was cleared of Wyoming big sagebrush, *Artemisia tridentata* spp. *wyomingensis*, and associated perennials and annual grasses. Cultural methods were used to control the weeds. The establishment of the fourwing saltbush garden has been described by Welch and Monsen (1981).

From this garden, 43 accessions of fourwing saltbush were selected to evaluate variations in winter *in vitro* digestibility, crude protein, and production. Table 1 lists the county and state where the seeds for each accession were collected. From each accession, five plants were selected at random for this study.

Current year's growth (leaves and stems) was collected at random throughout the entire crown of the plants during February 1980. Samples were placed in paper bags, transported to the laboratory, and allowed to air dry for 5 days. Then the samples were ground in a Wiley mill, passed through a 1 mm screen, and ovendried at 100° C for 48 hours. Total nitrogen was determined by the Kjeldahl method as outlined by the Association of Official Analytical Chemists (1980). Crude protein was calculated by multiplying the nitrogen content by 6.25 (Association of Official Analytical Chemists 1980). Digestibility was determined by the *in vitro* method described by Pearson (1970). *In vitro* digestibility was determined on the 31 accessions (13-43) containing the highest amount of crude protein. Data were expressed on a percent dry matter basis.

In August, 1981, productivity was determined for the same plants used in the digestibility and crude protein portion of this study. Ocular estimates were made of the annual herbage production for individual plants (Pechanec and Pickford 1937).

A completely random analysis of variance ($P > 0.01$) was used to detect significance among the fourwing saltbush accessions. Hartley's

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test (P > 0.05) was used to test for significant differences among accessions means for digestibility, crude protein, and production. Where needed, percentages were transformed to arcsin (Snedecor and Cochran 1967).

Table 1.--Location of the seed collecting sites for the 43 accessions of fourwing saltbush (Atriplex canescens) used in this study.

1. Juab Co., Utah (Jericho)
2. Kane Co., Utah (Kanab)
3. Washoe Co., Nevada (Reno Experimental Area)
4. Emery Co., Utah (Hiawatha)
5. San Juan Co., Utah (Monticello)
6. Owyhee Co., Idaho (Reynolds Creek)
7. Lincoln Co., Nevada (Panaca)
8. Sanpete Co., Utah (Fayette)
9. San Juan Co., Utah
10. Iron Co., Utah (Lund)
11. Delta Co., Colorado (Delta)
12. Unknown, Arizona (Little Colorado)
13. Navajo Co., Arizona (Keams Canyon)
14. Rio Arriba Co., New Mexico
15. Millard Co., Utah (Garrison)
16. Sweetwater Co., Wyoming (Green River)
17. Rio Arriba Co., New Mexico (Rincon Blanco)
18. Emery Co., Utah (Huntington)
19. Juab Co., Utah (Nephi)
20. Coconino Co., Arizona (Kaibab Nat'l. For.)
21. Emery Co., Utah (San Rafael Swell)
22. Juab Co., Utah (Excel Canyon)
23. Mesa Co., Colorado (Grand Junction)
24. Garfield Co., Utah (Escalante)
25. Iron Co., Utah (Cedar City)
26. Elmore Co., Idaho (Bliss)
27. Washington Co., Utah (St. George)
28. Uintah Co., Utah (Manila)
29. Carbon Co., Utah (Ivy Creek)
30. Beaver Co., Utah (Milford)
31. Sanpete Co., Utah (Ephraim)
32. Wasatch Co., Utah (Timpanogas)
33. Millard Co., Utah (Desert Range Exp. Stn.)
34. Washington Co., Utah (Pine Valley)
35. Gunnison Co., Colorado (Gunnison)
36. San Juan Co., Utah (Fry Canyon)
37. Juab Co., Utah (Tintic Valley)
38. San Juan Co., Utah (Mexican Hat)
39. Emery Co., Utah (Emery)
40. Coconino Co., Arizona (Tuba City)
41. Uintah Co., Utah (Randlett)
42. Bighorn Co., Montana (Decker)
43. Washington Co., Utah (Jackson Springs)[1]

[1]This collection is probably a synthetic composed of several accessions including the progenitor of 'Rincon' and native Jackson Springs fourwing saltbush.

RESULTS AND DISCUSSION

Winter crude protein levels of the 43 accessions ranged from 6.0 to 14.2 percent with a mean of 9.6 percent (Welch and Monsen 1981, table 2). Crude protein levels of 215 individual plants ranged from 5.3 to 17.1 percent. Analysis of variance detected significance due to accession. Hartley's test detected that some accessions contained significantly higher levels of winter crude protein than others (table 2). Accessions from Washington County, Utah (Jackson Springs); Bighorn County, Mont. (Decker); and Uintah County, Utah (Randlett) contained the highest amounts of winter crude protein. Accessions from Juab County, Utah (Jericho); Kane County, Utah (Kanab); and Washoe County, Nev. (Reno

Table 2.--Winter crude protein levels among 43 accessions of fourwing saltbush (Atriplex canescens) grown in a uniform garden (from Welch and Monsen 1981). Data expressed as a percent of dry matter and as a coefficient of variation (five replications per accession).

Accession number[1]	Percent crude protein	C.V.[3]
1	[2]6.0[a]	14.0
2	7.1[a]	17.3
3	7.5[ab]	11.4
4	7.6[ab]	16.0
5	7.7[ab]	7.1
6	7.7[ab]	9.9
7	7.8[abc]	16.4
8	7.9[abc]	19.9
9	8.0[abc]	18.5
10	8.0[abc]	24.1
11	8.1[abc]	8.4
12	8.1[abc]	12.3
13	8.2[abcd]	3.4
14	8.3[abcd]	15.9
15	8.3[abcd]	14.2
16	8.6[bcd]	23.5
17	8.7[bcd]	33.9
18	8.9[bcd]	24.1
19	9.0[bcd]	31.5
20	9.1[bcde]	16.3
21	9.2[bcde]	14.7
22	9.2[bcde]	7.2
23	9.3[bcde]	9.9
24	9.3[bcde]	10.4
25	9.5[bcde]	20.8
26	9.6[bcdef]	5.9
27	9.8[bcdef]	29.7
28	9.8[bcdef]	18.7
29	10.0[bcdef]	8.3
30	10.2[bcdef]	28.1
31	10.2[bcdef]	23.7
32	10.4[cdef]	14.2
33	10.6[cdef]	13.9
34	10.9[def]	28.4
35	11.5[efg]	22.8
36	11.7[efgh]	10.3
37	11.9[efgh]	16.7
38	12.0[fgh]	25.5
39	12.2[fgh]	22.7
40	12.9[gh]	27.8
41	13.8[gh]	11.2
42	14.1[gh]	21.5
43	14.2[h]	10.8

[1]For location of accessions, see table 1.
[2]Accessions sharing the same letter superscript are not significantly different at the 95 percent level.
[3]C.V. = Coefficient of variation (five replications per accession).

Experiment Station) contained the least amounts of winter crude protein. There was significant variation among plants within a given accession. This is illustrated in table 2 by the accessional coefficients of variation. The coefficients of variation ranged from 3.4 to 33.9 percent. The mean coefficient of variation was 17.2 percent. For those accessions with a large amount of variation, careful intra-accessional selection could greatly improve their winter crude protein levels.

The mean winter crude protein content of fourwing saltbush, 9.6 percent, compares favorably with the crude protein content of evergreen shrubs such as big sagebrush (Artemisia tridentata), 11.4 percent; black sagebrush (Artemisia nova), 11.7 percent; and curlleaf mountain mahogany (Cercocarpus ledifolius), 10.1 percent (table 3). Fourwing saltbush supplies more crude protein to the consuming animal than deciduous shrubs such as antelope bitterbrush (Purshia tridentata), Saskatoon serviceberry (Amelanchier alnifolia), and Gambel oak (Quercus gambelii) and supplies considerably more crude protein than dormant grass (table 3). In general, evergreen shrubs have a higher winter level of crude protein than deciduous shrubs, and deciduous shrubs have a much higher winter level of crude protein than dormant grasses (Cook 1972; Welch 1981; Welch 1983).

The crude protein requirement for wintering sheep and probably for mule deer is 8.9 percent (National Academy of Sciences 1975). Based on the data in table 2, 26 of the 43 accessions would meet or exceed the crude protein requirement for wintering sheep and deer. The winter crude protein requirement for cattle is 5.9 to 8.8 percent (Maynard and others 1979). It is apparent that certain accessions of fourwing saltbush could be used to increase the amount of crude protein on livestock and wildlife winter ranges (Welch 1983).

The in vitro digestibility of 31 accessions of fourwing saltbush ranged from 29.1 to 46.9 percent of dry matter digested. The mean was 38.3 percent (table 4). The in vitro digestibility of 155 individual plants ranged from 22.3 to 63.4 percent of dry matter digested.

Analysis of variance detected significant effects ($P > .01$) due to accession (table 4). Hartley's test detected that some accessions were more digestible than others($P > .05$). Accessions from Washington County, Utah (Jackson Springs); Coconino County, Ariz. (Tuba City); Bighorn County, Mont. (Decker); and Uinta County, Utah (Randlett) were among the most digestible. These four accessions also contained the highest amounts of winter crude protein. The relationship between crude protein and in vitro digestion was significantly related at a correlation coefficient of 0.88. The coefficient of determination was 0.78. As with crude protein levels, there was significant variation among plants within a given accession.

Table 3.--Winter crude protein content of selected range plants.

Range plant	Crude protein (percent dry matter)	Reference[1]
Black sagebrush	11.7	13
Big sagebrush	11.4	1,2,3,4,6, 8,9,10,13, 16,19
Curlleaf mountain mahogany	10.1	3,7
Fourwing saltbush	9.6	12
Chokecherry	8.7	3,5,11,17
Cliffrose	8.6	5,14
Desert bitterbrush	8.5	3,14
Rocky Mountain juniper	8.4	1
Antelope bitterbrush	7.8	1,3,4,7,8, 9,11,14
True mountain mahogany	7.8	1,5,9
Rubber rabbitbrush	7.8	1,11
Shadscale	7.7	10
Gardner saltbush	7.2	10
Utah juniper	6.6	3,5,7
Saskatoon serviceberry	5.9	3,11
Woods rose	5.8	17,18
Gambel oak	5.3	5,19
Apache-plume	4.8	14
Crested wheatgrass	3.9	11
Native grass	3.6	3
Wildrye	3.2	15
Indian ricegrass	3.0	11,15

[1]Reference:
1 - Dietz and others 1962
2 - Welch and McArthur 1979b
3 - Tueller 1979
4 - Bissell and others 1955
5 - Smith 1957
6 - Smith 1950
7 - Smith 1952
8 - Trout and Thiessen 1973
9 - Medin and Anderson 1979 (data converted to dry matter basis)
10 - National Academy of Sciences 1975
11 - National Academy of Sciences 1958
12 - Welch and Monsen 1981
13 - Sheehy 1975
14 - Welch and others 1983a
15 - National Academy of Sciences 1964
16 - Urness and others 1983
17 - Dietz 1972
18 - Welch and Andrus 1977
19 - Kufeld and others 1981

This is illustrated in table 4 by the accessional coefficients of variation. The coefficients of variation for the 31 accessions ranged from 4.5 to 28.0 percent with a low mean of 13.5 percent. For those accessions with a large amount of variation, careful intra-accessional selection could improve their winter digestibility.

The fourwing saltbush mean winter in vitro digestibility of 38.3 percent compares to 57.0 percent for bud sagebrush, 57.4 percent for big sagebrush, 50.0 percent for Indian ricegrass,

Table 4.--*In vitro* digestibility of winter samples of 31 accessions[1] of fourwing saltbush (*Atriplex canescens*) grown in a uniform garden. Data expressed as percent of digested dry matter and as a coefficient of variation (five replications per accession).

Accession	Percent of digestible dry matter	C.V.[3]
20	[2]29.1[a]	18.1
14	31.1[a]	7.9
16	31.8[ab]	16.5
13	32.1[ab]	4.5
17	32.5[ab]	27.1
18	33.7[abc]	16.8
27	34.0[abc]	19.1
22	35.0[abc]	10.6
28	35.5[abc]	15.4
23	35.7[abc]	11.7
25	36.0[abcd]	11.4
21	36.1[abcd]	4.5
19	36.2[abcd]	13.7
26	36.3[abcd]	9.1
30	36.3[bcd]	15.5
24	36.6[bcd]	9.2
15	37.0[bcd]	10.0
34	39.5[cde]	14.1
29	40.4[cdef]	8.4
32	40.5[cdef]	17.0
38	40.6[cdef]	17.9
36	40.9[cdef]	13.0
33	41.2[def]	6.8
37	42.9[def]	12.6
35	43.4[ef]	8.0
31	44.4[ef]	28.0
39	45.3[ef]	19.3
41	45.3[ef]	11.5
42	46.2[ef]	21.0
40	46.2[ef]	11.1
43	46.9[f]	10.0

[1]For location of accessions, see table 1.
[2]Accessions sharing the same letter superscript are not significantly different at the 95 percent level.
[3]C.V. = coefficient of variation (five replications per accession).

28.1 percent for Gambel oak, and 25.4 percent for antelope bitterbrush. (For additional range forages and references, see table 5).

The digestibility requirement for winter white-tailed deer and probably mule deer is about 50 percent (Ammann and others 1973). Even the most digestible accession of fourwing saltbush falls short. This points to the need for mixing range plants higher in digestibility, such as big sagebrush and dormant grasses, in with the fourwing saltbush.

The productivity of the accessions of fourwing saltbush ranged from 197 to 1 451 grams per plant (table 6). McArthur and others (1983) have reported similar results. On an individual plant basis, productivity ranged from 45 to 2 000 grams. The mean for all plants was 664

Table 5.--*In vitro* digestibility of winter range forages. Data expressed as a percent of digested dry matter.

Shrub	Dry matter digestibility (percent)	Reference[1]
Big sagebrush	57.4	1,2,3,4,5, 6,11
Bud sagebrush	57.0	8
Sand dropseed grass	53.2	3,8
Black sagebrush	53.1	8
Indian ricegrass	50.0	6,8
Curlleaf mountain mahogany	49.1	1,4
Rosehips (Sweetbrier rose)	49.1	4
Winterfat	44.7	8
Rubber rabbitbrush	44.4	6
Shadscale	43.4	8
Chokecherry	38.8	7,10
Fourwing saltbush	38.3	12
Stansbury cliffrose	37.6	9
Desert bitterbrush	35.8	9
Saskatoon serviceberry	34.6	6
Apache-plume	29.8	9
Gambel oak	28.1	5
Antelope bitterbrush	25.4	1,4,6,9
True mountain mahogany	24.3	1,4

[1]Reference:
1 - Urness and others 1977
2 - Wallmo and others 1977
3 - Sheehy 1975
4 - Welch and Pederson 1981
5 - Kufeld and others 1981
6 - Ward 1971
7 - Uresk and others 1975
8 - Welch and others 1983b
9 - Welch and others 1983a
10 - Dietz 1972
11 - Pederson and Welch 1982
12 - This study

grams. McArthur[1] found productivity of a released variety of fourwing saltbush, 'Rincon', to be 4 400 grams on one site and 2 600 grams on a second site.

Analysis of variance detected significance (P > .01) due to accession (table 6). Hartley's test detected that some accessions were more productive than others (P > .05). Accessions from Arizona (Little Colorado); Navajo County, Ariz. (Keams Canyon); and Emery County, Utah (Emery) were among the most productive. There was significant variation among plants within an accession. This is illustrated in table 6 by the accessional coefficients of variation. The coefficients of variation for the accessions ranged from 7.4 to 96.3 percent. The mean coefficient of variation was 44.9 percent. Intra-accessional variation is much greater for

[1]McArthur, E. D. Unpublished data on file at the Shrub Sciences Laboratory, Provo, Utah.

productivity than for crude protein (17.2 percent) or *in vitro* digestibility (13.5 percent). For those accessions with a large amount of variation, careful intra-accessional selection could improve their productivity.

Table 6.--Productivity among 41 accessions[1] of fourwing saltbush (*Atriplex* canescens) grown in a uniform garden.

Accession number	Grams of forage	C.V.[3]
10	197[a]	83.8
42	231[a]	65.5
28	287[a]	96.3
35	367[ab]	81.8
34	401[ab]	37.5
21	405[ab]	38.8
37	415[ab]	53.9
7	424[ab]	40.0
11	428[ab]	40.5
36	432[ab]	45.0
26	476[abc]	55.5
3	493[abc]	44.4
17	504[abc]	43.8
24	515[abc]	28.5
32	523[abc]	47.6
5	524[abc]	36.5
22	577[abcd]	43.0
4	581[abcd]	59.3
15	587[abcd]	70.9
6	596[bcd]	50.5
25	667[bcd]	51.9
9	700[bcde]	27.8
8	730[bcde]	7.4
33	754[bcde]	30.8
38	762[cde]	57.6
40	766[cde]	25.1
20	783[cde]	23.8
14	840[cdef]	32.2
27	842[cdef]	39.2
19	846[cdef]	28.7
2	867[cdef]	46.7
41	918[def]	47.0
30	968[def]	43.2
43	975[ef]	39.2
23	985[ef]	16.0
18	991[ef]	12.7
29	1000[ef]	29.2
39	1069[efg]	74.6
13	1101[fg]	59.5
12	1451[g]	42.1

[1] For location of accessions, see table 1.
[2] Accessions sharing the same letter superscript are not significantly different at the 95 percent level.
[3] C.V. = coefficient of variation (five replications per accession).

It should be noted that the accession of fourwing saltbush from Washington County, Utah (Jackson Springs) contained the highest winter level of crude protein (14.2 percent), was the most digestible, and had a productivity well above the average at 975 grams. It may be possible to increase the productivity of the Jackson Springs fourwing saltbush accession by crossing it with the Little Colorado fourwing accession.

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PUBLICATIONS CITED

Ammann, A. P.; Cowan, R. L.; Mothershead, C. L.; Baumgardt, B. R. Dry matter and energy intake in relation to digestibility in white-tailed deer. J. Wildl. Manage. 37: 195-201; 1973.

Association of Official Analytical Chemists. Official methods of analysis. 13th ed. Washington, DC: 1980. 1018 p.

Bissell, H. D.; Harris, B.; Strong, H.; James F. The digestibility of certain natural and artificial food eaten by deer in California. California Fish and Game 41: 57-78. 1955.

Cook, C. W. Comparative nutritive values of forbs, grasses, and shrubs. In: McKell, C. M.; Blaisdell, J. P.; Goodin, J. R., eds. Wildland shrubs--their biology and utilization: proceedings of symposium; 1971, July; Logan, UT. Res. Pap. INT-1. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1972: 303-310.

Dietz, D. R. Nutritive value of shrubs. In: McKell, C. M.; Blaisdell, J. P.; Goodin, J. R., eds. Wildland shrubs--their biology and utilization: proceedings of symposium; 1971 July; Logan, UT. Res. Pap. INT-1. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1972: 289-302.

Dietz, D. R. Deer nutrition research in range management. Trans. North Am. Wildl. and Nat. Resour. Conf. 30: 274-285; 1965.

Dietz, D. R.; Udall, R. H.; Yeager, L. E. Chemical composition and digestibility by mule deer of selected forage species, Cache La Poudre Range, Colorado. Tech. Publ. 14. Denver, CO: Colorado Fish and Game Department; 1962. 89 p.

Ensminger, M. E.; Olentine, C. G. Feed and nutrition-abridged. Clovis, CA: Ensminger Publishing; 1978. 824 p.

Halls, L. K. Nutrient requirement of livestock and game. In: Paulsen, H. A.; Reid, E. H.; Parker, K. W., eds. Range and wildlife habitat evaluation-a range symposium: proceedings of symposium; 1968 May; Flagstaff and Tempe, AZ.

Publ. 1147. Washington, DC: U.S. Department of Agriculture, Forest Service; 1970: 10-18.

Kufeld, R. C.; Stevens, M.; Bowden, D. C. Winter variation in nutrient and fiber content and in vitro digestibility of Gambel oak (Quercus gambelii) and big sagebrush (Artemisia tridentata) from diversified sites in Colorado. J. Range Manage. 34: 149-151; 1981.

Maynard, L. A.; Loosli, J. K.; Hintz, H. F.; Warner, R. G. Animal nutrition. 7th ed. New York: McGraw-Hill; 1979. 602 p.

McArthur, E. D.; Plummer, A. P.; Van Epps, G. A.; Freeman, D. C.; Jorgensen, K. R. Producing fourwing saltbush seed in seed orchards. In: Hyder, D. N., ed. Proceedings of first international rangeland congress; 1978 August; Denver, CO: Soc. for Range Management; 1978: 406-410.

McArthur, E. D.; Stevens, R.; Blauer, A. C. Growth performance comparisons among 18 accessions of fourwing saltbush (Atriplex canescens) at two sites in central Utah. J. Range Manage. 36: 78-81; 1983.

Medin, D. E.; Anderson, A. E. Modeling the dynamics of a Colorado mule deer population. Wildl. Monogr. 68. Washington, DC: The Wildlife Society; 1979. 77 p.

Nagy, J. G.; Wallmo, O. C. Deer nutrition problems in the USA. In: proceedings of the world exhibition and hunting conference of game managers; 1971 September; Budapest, Hungary. Sopron, Hungary: University Press; 1972: 59-68.

National Academy of Sciences. Composition of cereal grains and forages. Publ. 585. Washington, DC: National Research Council; 1958. 663 p.

National Academy of Sciences. Nutrient requirements of domestic animals. No. 5. Nutrient requirements of sheep. Publ. 1193. Washington, DC: National Research Council; 1964. 36 p.

National Academy of Sciences. Nutrient requirements of domestic animals. No. 5. Nutrient requirements of sheep. 5th ed. Washington, DC: National Research Council; 1975. 72 p.

Pearson, H. A. Digestibility trials: In vitro techniques. In: Paulson, H. A.; Reid, E. H.; Parker, K. W., eds. Range and wildlife habitat evaluation--a range symposium: proceedings of symposium; 1968 May; Flagstaff and Tempe, AZ. Publ. 1147. Washington, DC: U.S. Department of Agriculture, Forest Service; 1970: 85-92.

Pechanec, J. F.; Pickford, G. D. A weight estimate method for determination of range or pasture production. J. Agron. 29: 894-904; 1937.

Pederson, J. C.; Welch, B. L. Effects of monoterpenoid exposure on ability of rumen inocula to digest a set of forages. J. Range Manage. 35: 500-502; 1982.

Sheehy, D. P. Relative palatability of seven Artemisia taxa to mule deer and sheep. Corvallis, OR: Oregon State University; 1975. 147 p. M.S. Thesis.

Smith, A. D. Sagebrush as winter feed for mule deer. J. Wildl. Manage. 14: 285-289; 1950.

Smith, A. D. Digestibility of some native forages for mule deer. J. Wildl. Manage. 16: 309-312; 1952.

Smith, A. D. Nutritive value of some browse plants in winter. J. Range Manage. 10: 162-164; 1957.

Snedecor, G. W.; Cochran, W. G. Statistical methods. Ames, IA: The Iowa State University Press; 1967. 593 p.

Trout, L. E.; Thiessen, J. L. Physical condition of range relationships of the Owyhee deer herd. Boise, ID: Idaho Fish and Game Department; 1973. 37 p. Job completion report.

Tueller, P. T. Food habits and nutrition of mule deer on Nevada ranges. Reno, NV: University of Nevada, Nevada Agricultural Experiment Station; 1979. 104 p.

Urness, P. J.; Austin, D. D.; Fierro, L. C. Nutritional value of crested wheatgrass for wintering mule deer. J. Range Manage. 36: 225-226; 1983.

Urness, P. J.; Smith, A. D.; Watkins, R. K. Comparison of in vivo and in vitro dry matter digestibility of mule deer forages. J. Range Manage. 30: 119-121; 1977.

Uresk, D. W.; Messner, H. E. Constituents in in vitro solution contribute differently to dry matter digestibility of deer food species. J. Range Manage. 28: 419-421; 1975.

Van Epps, G. A.; McKell, C. M. Major criteria and procedures for selecting and establishing range shrubs as rehabilitators of disturbed lands. In: Hyder, D. N., ed. Proceedings of the first international rangeland congress; 1978, August; Denver, CO: Society for Range Manage; 1978: 352-354.

Wallmo, O. C.; Carpenter, L. H.; Regelin, W. L.; Gill, R. B.; Baker, D. L. Evaluation of deer habitat on a nutritional basis. J. Range Manage. 30: 122-127; 1977.

Ward, A. L. In vitro digestibility of elk winter forage in southern Wyoming. J. Wildl. Manage. 35: 681-688; 1971.

Welch, B. L. Nutritive value of big sagebrush and other shrubs. In: Stelter, L. H.; DePuit, E. J.; Mikol, S. A., eds. Shrub establishment on disturbed arid and semi-arid lands: proceedings of symposium; 1980 December. Laramie, WY: Wyoming Game and Fish Department; 1981: 9-22.

Welch, B. L. Nutritive qualities of shrubs. In: Monsen, S. B.; Shaw, N. L., eds. Managing Intermountain rangelands--improvement of range and wildlife habitats; 1981 September 15-17; Twin Falls, ID; 1982 June 22-24, Elko, NV. Gen. Tech. Rep. INT-157. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1983: 158-164.

Welch, B. L.; Andrus, D. Rose hips--a possible high-energy food for wintering mule deer? Res. Note INT-221. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 1977.

Welch, B. L.; McArthur, E. D. Feasibility of improving big sagebrush (Artemisia tridentata) for use on mule deer winter ranges. In: Goodin, J. R.; Northington, D. K., eds. Arid land plant resources: proceedings of the international arid lands conference on plant resources; 1978 October. Lubbock, TX: International center for arid and semi-arid land studies, Texas Tech University; 1979a: 451-473.

Welch, B. L.; McArthur, E. D. Variation in winter levels of crude protein among Artemisia tridentata subspecies grown in a uniform garden. J. Range Manage. 32: 467-469; 1979b.

Welch, B. L.; Monsen, S. B.; Shaw, N. L. Nutritive value of antelope and desert bitterbrush, Stansbury cliffrose, and apache-plume. In: Tiedemann, A. R.; Johnson, K. L., eds. Proceedings--research and management of bitterbrush and cliffrose in Western North America; 1982 April 13-15; Salt Lake City, UT. Gen. Tech. Rep. INT-152. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1983a: 173-185.

Welch, B. L.; Monsen, S. B. Winter crude protein among accessions of fourwing saltbush grown in a uniform garden. Great Basin Naturalist. 41: 343-346; 1981.

Welch, B. L.; Pederson, J. C. In vitro digestibility among accessions of big sagebrush by wild mule deer and its relationship to monoterpenoid content. J. Range Manage. 34: 497-500; 1981.

Welch, B. L.; Pederson, J. C.; Clary, W. P. Ability of rumen inoculum sources to digest a set of range forages. J. Wildl. Manage. 47: 873-877; 1983b.

In: Tiedemann, Arthur R.; McArthur, E. Durant; Stutz, Howard C.; Stevens, Richard; Johnson, Kendall L., compilers. Proceedings--symposium on the biology of Atriplex and related chenopods; 1983 May 2-6; Provo, UT. General Technical Report INT-172. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 309 p.

SEASONAL VARIATION IN CRUDE PROTEIN CONTENT OF KOCHIA PROSTRATA (L.) SCHRAD.

James N. Davis and Bruce L. Welch

ABSTRACT: Seasonal crude protein content was determined on composite samples of thirteen accessions of Kochia prostrata (perennial summer cypress) grown in a uniform garden. The plants were divided into two stem parts, "upper" and "lower." Mean crude protein content was highest during July (14.4 percent) through November (10.2 percent) for "upper" stem parts. For the "lower" stem parts, highest mean protein content was May (12.8 percent) through July (14.0 percent). Accessional differences were not statistically tested; however, differences among accessions were noted. Best use of Kochia prostrata as a forage appears to be on fall ranges.

INTRODUCTION

Kochia prostrata, or perennial summer cypress, is being tested as a potential forage plant for western United States ranges. One accession, P.I. 314929 (U-2), has just gone through the final stages of the Soil Conservation Service release process. It has been named 'Immigrant' forage kochia for commercial production and marketing of seed. Perennial summer cypress is a widely distributed shrub native to the arid and semiarid regions of Central Asia and from Southern Europe and Northern Africa to Manchuria (Moghaddam 1978). Ecotypic variation has been noted, e.g. with its height varying from less than a foot (30 cm) to over 4 feet (120 cm) (Balyan 1972; Francois 1976; Keller and Bleak 1974; McArthur and others 1974). Kochia prostrata was first introduced to the United States from the U.S.S.R. during the early 1960's (Keller and Bleak 1974). It is often associated with crested wheatgrass in sandy soil because of its deep rooted nature (to 16.4 ft [5 m]) (Prianshnikov 1966). Limited nutritive studies have been conducted. Davis (1979) reported winter (January and March) crude protein varied from 6.2 to 12.5 percent. He also reported winter carotene varied from 1.3 to 11.1 mg/100 g of dry matter. Welch and Davis[1] reported winter in vitro digestibility of K. prostrata varied from 20.2 to 38.0 percent of dry matter digested. We undertook this study to determine the seasonal crude protein content of accessions of Kochia prostrata.

MATERIALS AND METHODS

Thirteen accessions of K. prostrata were selected to study seasonal variation in crude protein content. The accessions were grown in a uniform garden at the Snowfield Station, Ephraim, Utah. Sources of the genetic materials for the accessions used in this study are given in table 1. For each accession, five plants were selected at random to furnish a composite sample. The same plants were sampled throughout the study. A composite sample was needed to ensure tissue enough to last throughout the plants' dormant condition within the study period. Vegetative samples were collected during the first week of the

Table 1.--Plant introduction numbers, U-numbers of the Utah Wildlife Resources (W-82-R), soil types, and location for Kochia prostrata accessions used in this study.

P.I. number	U. number	Soil type	Location
330708	U-1	*[1]	Tehran, Iran
314929	U-2	*	Stavropol, USSR
*	U-3	*	Yun Dudar, USSR
356824	U-5	Salty	Actobinsk, USSR
356823	U-6	Sandy	Actobinsk, USSR
586822	U-7	Clay	Ural Mountains, USSR
356821	U-8	Salty	Actobinsk, Aral Sea, USSR
356825	U-9	Clay	Actobinsk, USSR
356826	U-10	Salty	Actobinsk, Ural Mtns., USSR
356819	U-11	Salty	Actobinsk, Aral Sea, USSR
356820	U-12	Sandy	Actobinsk, Aral Sea, USSR
356818	U-13	Clay	Actobinsk, Aral Sea, USSR
356817	U-14	Salty	Actobinsk, Aral Sea, USSR

[1]*=Information not available

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[1]Welch, B. L.; Davis, J. N. In vitro digestibility of Kochia prostrata (L.) Shrad. Great Basin Naturalist. In press.

following months: December, January, February, March, April, May, July, and November (1980-81). The stems varied from about 24 to 30 inches (61 to 76 cm) in length. During most of the year, K. prostrata plants consist of two types of tissues, which we call "upper" and "lower" (remainder of stem) parts of the stem. The "upper" stem is that part of the stem where seeds are developing (spring and summer) or have shed (fall and winter) leaving a dry, brownish, somewhat erect vegetative stem. The "lower" stem is that part of the stem where green leaves are attached. Both types of tissue were sampled from the selected plants. Samples were oven dried at 212° F (100° C) for 48 hours. Then they were ground with a Wiley mill and passed through a 1-mm screen. Ground samples were stored at -34° F (-35°C) in airtight containers.

We used the Kjeldahl method for determining crude protein content (Association of Official Analytical Chemists 1980). Data were expressed as percent of dry matter. A paired t-test was used to detect differences between "upper" and "lower" stem samples for each month and through the 12-month period. Analysis of variance was used to detect significant differences ($p > 0.05$) among months for "upper" and "lower" stem parts. Accessions were replications. Newmann-Kuels multiple range test was used to detect significant differences among treatment means.

RESULTS AND DISCUSSION

Analysis of variance detected significant differences by months for both the "upper" and "lower" stem parts. For the "upper" stem parts, K. prostrata contained significantly higher crude protein in July and November than in the other months (table 2). Crude protein content for the "lower" stem part was significantly higher in May and July. Davis (1979) showed a similar seasonal pattern. Paired t-tests detected significant crude protein content differences between "upper" and "lower" stem parts. "Lower" stem parts contained significantly more crude protein for the months of December through May. "Upper" stem parts contained significantly more crude protein in November than the "lower" stem parts. During January, February, and March, the mean crude protein for the "upper" stem parts was 5.8 percent and for the "lower" stem parts it was 8.4 percent.

Some accessions appeared to contain more winter crude protein than others (table 3), but because sampling was composite, accessional differences could not be statistically tested. Protein content of the "lower" stem parts by accession ranged from a low of 8.6 percent (U-7) to a high of 11.3 percent (U-3), with a mean of 9.9 percent. Combining the crude protein of "upper" and lower" stem parts, U-3 contained 9.1 percent winter crude protein; U-5 contained 8.6 percent; U-1 and U-2 contained 8.4 percent. U-11 contained the least amount of winter crude protein at 5.9 percent. Of special interest was the high crude protein content of U-1 "upper" stem parts in November (19.5 percent) and December (13.8 percent). Other accessions (U-2, U-3, U-5) had high crude protein content during November (15.1 to 18.1 percent), but substantially lower levels in December (5.5 to 7.1 percent). This high level in November and low level in December (except for U-1) was probably due to seed shedding between November and December. If this is true, energy levels of the "upper" stem parts were also probably high (Ensminger and Olentine 1978).

U-1 (and perhaps U-2, U-3, U-5) has the potential of supplying high levels of crude protein on fall ranges. Perennial summer cypress also has value as early spring forage. We found that early spring growth had crude protein values ranging from 12.1 to 21.8 percent with a mean of 18.0 percent.

Kochia prostrata's usefulness to supply winter crude protein is dependent on the stem part ("upper" or "lower") and accession being eaten. The overall winter crude protein content of the "lower" stem part was higher at 8.4 percent (table 4); however, "lower" stem parts may be covered with snow and thus not be available for animal consumption where snow accumulates deeper than 19.71 inches (50 cm). On an accessional basis, the winter crude protein content of the "upper" stem parts varied from 2.8 to 8.7 percent, and varied from 5.4 to 10.9 percent for "lower" stem parts.

Table 2.--Crude protein content of "upper" and "lower" stems of Kochia prostrata across 7 months. Data expressed as percent of dry matter.

Stem	Month							
part	Dec.	Jan.	Feb.	Mar.	Apr.	May	July	Nov.
Upper	5.9[a1]	6.1[a]	6.1[a]	5.2[a]	5.7[a]	5.8[a]	14.4[b]	10.7[b]
Lower	8.2[a]	8.3[a]	8.7[a]	9.8[a]	9.8[a]	12.8[b]	14.0[b]	8.6[a]

[1]Values sharing the same letter superscript are not significantly different at the 95 percent level.

Table 3.--The seasonal crude protein content of "upper" and "lower" stems among accessions of *Kochia prostrata*. Data expressed as percentage of dry matter.

Accession	Month							
	Dec.	Jan.	Feb.	Mar.	Apr.	May	July	Nov.
U-1-U[1]	13.8	8.5	7.9	7.6	6.2	6.2	14.1	19.5
U-1-L[2]	7.3	8.1	9.5	8.7	8.4	14.6	14.2	9.4
U-2-U	6.9	8.5	7.8	7.3	6.9	6.1	13.7	9.4
U-2-L	10.1	8.7	9.0	8.9	9.1	14.2	13.8	8.9
U-3-U	7.1	8.2	8.7	6.8	8.2	8.0	15.8	17.5
U-3-L	9.4	10.6	10.9	9.3	9.3	15.9	12.6	10.2
U-5-U	5.5	7.3	7.3	8.7	5.0	9.2	15.2	18.1
U-5-L	8.8	9.6	9.1	9.9	8.1	17.3	13.2	10.5
U-6-U	4.8	5.4	6.0	4.9	6.6	5.5	14.6	8.5
U-6-L	6.5	8.1	6.5	7.2	7.3	11.4	13.2	7.3
U-7-U	4.0	4.7	5.4	3.2	4.0	4.7	12.9	4.9
U-7-L	12.4	9.2	9.7	6.8	14.6	10.3	10.7	7.2
U-8-U	4.4	3.8	4.5	3.8	4.7	4.9	15.2	7.1
U-8-L	5.8	7.8	8.7	8.5	11.9	10.2	13.7	7.9
U-9-U	4.2	5.2	4.2	3.7	4.0	4.7	14.3	6.6
U-9-L	6.3	8.2	8.9	9.4	10.1	15.2	13.6	7.7
U-10-U	6.6	7.0	6.4	4.6	4.8	5.4	13.9	11.1
U-10-L	8.3	8.0	8.9	8.6	9.8	11.8	15.1	9.0
U-11-U	4.9	4.4	4.9	2.8	4.7	4.1	14.0	8.0
U-11-L	7.3	8.0	8.0	7.2	8.0	11.8	17.3	8.4
U-12-U	5.6	4.9	4.5	5.3	5.2	5.3	13.6	9.8
U-12-L	9.0	7.9	8.3	7.0	7.9	11.1	14.2	9.0
U-13-U	5.1	7.4	5.1	4.7	7.1	5.6	14.4	4.4
U-13-L	8.6	7.8	8.6	5.7	12.1	11.1	14.8	7.3
U-14-U	5.1	4.3	7.3	4.2	6.1	5.1	15.1	8.3
U-14-L	6.2	5.4	7.0	8.0	11.0	11.0	15.3	8.6
Mean - U	6.0	6.1	6.2	5.2	5.7	5.8	14.4	10.2
Mean - L	8.7	8.3	8.7	8.1	9.8	12.8	14.0	8.6

[1] U="upper" part of stem.
[2] L="lower" part of stem.

Because of position of the most nutritious part, and varying snow depths, the value of *K. prostrata* as a winter forage is difficult to evaluate. Its winter *in vitro* digestion is also low (see footnote 1). The best use of *K. prostrata* as a forage appears to be on fall ranges. (See p. 148 for table 4.)

ACKNOWLEDGMENTS

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PUBLICATIONS CITED

Association of Official Analytical Chemists. Official methods of analysis. 13th ed. Washington, DC: Association of Official Analytical Chemists; 1980. 1018 p.

Balyan, G. A. Prostrate summer cypress and its culture in Kirghizia. Elias, A., ed. Washington, DC: U.S. Department of Commerce, National Technical Information Service; 1972. 296 p. Translated from Russian.

Bissell, H. D.; Harris, B.; Strong, H.; James, F. The digestibility of certain natural and artificial food eaten by deer in California. California Fish and Game 41: 57-78; 1955.

Davis, A. M. Forage quality of prostrate Kochia compared with three browse species. Agron. J. 71: 822-824; 1979.

Table 4.--Winter crude protein content of selected range plants.

Range plant	Crude protein (percent of dry matter)	Reference
Black sagebrush	11.7	13
Big sagebrush	11.4	1,2,3,4,6,8,9,10,13,16,19
Curlleaf mountain mahogany	10.1	3,7
Fourwing saltbush	9.6	12
Chokecherry	8.7	3,5,11,17
Cliffrose	8.6	5,14
Desert bitterbrush	8.5	3,14
Rocky Mountain juniper	8.4	1
Kochia prostrata-U-2	8.4	This study
Antelope bitterbrush	7.8	1,3,4,7,8,9,11,14
True mountain mahogany	7.8	1,5,9
Rubber rabbitbrush	7.8	1,11
Shadscale	7.7	10
Gardner saltbush	7.2	10
Kochia prostrata	7.1	This study
Utah juniper	6.6	3,5,7
Saskatoon serviceberry	5.9	3,11
Woods rose	5.8	17,18
Gambel oak	5.3	5,19
Apache-plume	4.8	14
Crested wheatgrass	3.9	11
Native grass	3.6	3
Wildrye	3.2	15
Indian ricegrass	3.0	11,15

1 - Dietz and others 1962
2 - Welch and McArthur 1979
3 - Tueller 1979
4 - Bissell and others 1955
5 - Smith 1957
6 - Smith 1950
7 - Smith 1952
8 - Trout and Thiessen 1973
9 - Medin and Anderson 1979 (data converted to dry matter basis)
11 - National Academy of Sciences 1975
12 - National Academy of Sciences 1975
13 - Sheehy 1975
14 - Welch and others 1983
15 - National Academy of Sciences
16 - Urness and others 1983
17 - Dietz 1972
18 - Welch and Andrus 1977
19 - Kufeld and others 1981

Dietz, D. R. Nutritive value of shrubs. In: McKell, C. M.; Blaisdell, J. P.; Goodin, J. R., eds. Wildland shrubs--their biology and utilization; Proceedings of symposium: 1971 July; Logan, UT. Gen. Tech. Rep. INT-1, Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1972; 289-302.

Dietz, D. R.; Udall, R. H.; Yeager, L. E. Chemical composition and digestibility by mule deer of selected forage species, Cache La Poudre Range, Colorado. Tech. Publ. 14. Denver, CO: Colorado Fish and Game Department; 1962. 89 p.

Ensminger, M. E.; Olentine, C. G. Feed and nutrition--abridged. Clovis, CA: Ensminger Publishing Co.; 1978. 824 p.

Francois, L. E. Salt tolerance of prostrate summer cypress (*Kochia prostrata*). Agron. J. 68: 455-456; 1976.

Keller, W.; Bleak, A. T. *Kochia prostrata*: a shrub for western ranges? Utah Science. 34: 24-25; 1974.

Kufeld, R. C.; Stevens, M.; Bowden, D. C. Winter variation in nutrient and fiber content and *in vitro* digestibility of Gambel oak (*Quercus gambelii*), and big sagebrush (*Artemisia tridentata*) from diversified sites in Colorado. J. Range Manage. 34: 149-151; 1981.

McArthur, E. D.; Giunta, B. C.; Plummer, A. P. Shrubs for restoration of depleted ranges and disturbed areas. Utah Science. 35: 28-33; 1974.

Medin, D. E.; Anderson, A. E. Modeling the dynamics of a Colorado mule deer population. Wildl. Monogr. 68. Washington, DC: The Wildlife Society; 1979. 77 p.

Moghaddam, M. R. Kochia prostrata--a plant material for range improvement in arid and semiarid regions. Rangemen J. 5: 153-154; 1978.

National Academy of Sciences. Composition of cereal grains and forages. Publ. 585. Washington, DC: National Research Council; 1958. 663 p.

National Academy of Sciences. Nutrient requirements of domestic animals. No. 5. Nutrient requirements of sheep. Publ. 1193. Washington, DC: National Research Council; 1964. 36 p.

National Academy of Sciences. Nutrient requirements of domestic animals. No. 5. Nutrient requirements of sheep 5th ed. Washington, DC: National Research Council; 1975. 72 p.

Prianshnikov, S. Improvement and rational utilization of semidesert and desert pastures of Kazakh S.S.R.. In: The introduction of wild growing of fodder plants. Alma ata USSR: 1966.

Sheehy, D. P. Relative palatability of seven Artemisia taxa to mule deer and sheep. Corvallis, OR: Oregon State University; 1975. 147 p. M.S. thesis.

Smith, A. D. Sagebrush as winter feed for mule deer. J. Wildl. Manage. 14: 285-289; 1950.

Smith, A. D. Digestibility of some native forages for mule deer. J. Wildl. Manage: 16: 309-312; 1952.

Smith, A. D. Nutritive value of some browse plants in winter. J. Range Manage. 10: 162-164; 1957.

Trout, L. E.; Thiessen, J. L. Physical condition of range relationships of the Owyhee deer herd. Job Completion Report. Boise, ID: Idaho Fish and Game Department; 1973. 37 p.

Urness, P. J.; Austin, D. D.; Fierro, L. C. Nutritional value of crested wheatgrass for wintering mule deer. J. Range Manage. 36: 225-226; 1983.

Welch, B. L.; Andrus, D. Rose hips--a possible high-energy food for wintering mule deer? Res. Note INT-221. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1977. 6 p.

Welch, B. L.; McArthur, E. D. Variation in winter levels of crude protein among Artemisia tridentata subspecies grown in a uniform garden. J. Range Manage. 32: 467-469; 1979.

Welch, B. L.; Monsen, S. B. Winter crude protein among accessions of fourwing saltbush grown in a uniform garden. Great Basin Naturalist. 41: 343-346; 1981.

Welch, B. L.; Monsen, S. B.; Shaw, N. L. Nutritive value of antelope and desert bitterbrush, Stansbury cliffrose, and apache-plume. In: Tiedemann, A. R.; Johnson, K. L., eds. Proceedings--research and management of bitterbrush and cliffrose in Western North America. Gen. Tech. Rep. INT-152. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1983: 173-185.

In: Tiedemann, Arthur R.; McArthur, E. Durant; Stutz, Howard C.; Stevens, Richard; Johnson, Kendall L., compilers. Proceedings--symposium on the biology of Atriplex and related chenopods; 1983 May 2-6; Provo, UT. General Technical Report INT-172. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 309 p.

Section 4. Seed Physiology

OVERCOMING SEED DORMANCY IN GARDNER SALTBUSH (ATRIPLEX GARDNERI (MOQ.) D. DIETR.) AS A STRATEGY FOR INCREASING ESTABLISHMENT BY DIRECT SEEDING

R. James Ansley and Rollin H. Abernethy

ABSTRACT: Two seed-related factors, dormancy and seedling vigor, contribute to the lack of success in direct seedings of shrub species, including Gardner saltbush. Alleviation of seed dormancy to varying degrees has been obtained by applying combinations of pregermination seed treatments to Gardner saltbush seeds. Evidence from field studies indicates that seedling vigor plays a key role in successful Gardner saltbush seedling establishment.

INTRODUCTION

Gardner saltbush (*Atriplex gardneri* (Moq.) D. Dietr.) is a low growing perennial half shrub 8-20 in (20-50 cm) high which occurs in cold desert regions of Montana and Wyoming (Stubbendieck and others 1981). It is particularly adapted to saline, alkaline, and clayey soil conditions, extreme temperatures, high winds, and aridity. On rangeland and disturbed lands, it is a valuable winter forage and serves as a site stabilizer in areas where grasses are not predominant.

Revegetation with Gardner saltbush and related xerophytic shrub species by direct seeding has often been unsuccessful (Bleak and others 1965; McKell 1979; DePuit and Coenenberg 1980). In addition to environmental constraints, two physiological factors, seed dormancy and poor seedling vigor, may be responsible for failures of direct seeding (Malcolm 1972, Van Epps and McKell 1980).

The overall goal of the research reported here was to increase the reliability and effectiveness of direct seeding as a strategy for establishing Gardner saltbush. Research efforts concentrated on manipulating and/or characterizing the two physiological factors, seed dormancy and seedling vigor. If germination could be increased by overcoming dormancy, then pretreating seeds to overcome dormancy prior to planting could potentially increase establishment by direct seeding. Therefore, the first objective of the study was to develop seed pretreatments which would enhance germination, be economical, and be easy to apply. Additionally, germination response to seed pretreatments can provide correlative information about the physiological and ecological nature of dormancy in Gardner saltbush seeds.

The second objective of the study was to observe seedling vigor by determining field emergence of seed to which pretreatments had been applied and comparing that to laboratory germination of similarly pretreated seed. We did not attempt to improve seedling vigor in this study, but we did want to evaluate the relative effects of dormancy and seedling vigor on establishment of this species.

MATERIALS AND METHODS

Seed Procurement

Seeds were collected in August 1980 and 1981 from three distinct regionally isolated populations of Gardner saltbush 9 to 44 mi (15-70 km) west of Rawlins in the Red Desert Basin of south central Wyoming. The three seed populations were 'Knobs', 'Rasmussen', and 'Red Desert', named after the exits on Interstate-80 nearest them. The elevation ranges from 6660 to 6693 ft (2030-2040 m); average annual precipitation is 5.5 to 7.0 in (14 to 18 cm). Average mean monthly temperatures range from 28° to 68° F (-2° to 20° C) with extremes from -38° F (-39° C) in January to 106° F (41° C) in July (Becker and Alyea 1964). Gardner saltbush exists predominantly as a monoculture at each site. Soils are silt loams with moderate to high electrical conductivities and sodium absorption ratios (Ansley 1983).

Seeds were collected by hand stripping. Freshly harvested seeds were spread on a canvas tarp to air dry. Impurities were removed via screening with a 0.19 in^2 (5 mm^2) mesh and with a "Dakota" adjustable plexiglass column blower (Young and others 1978). Seed fill was determined by slicing 15 replicates of 100 utricles with a razor blade.

Seed Pretreatments

To overcome dormancy, seeds were exposed to scarification (Sc), washing (W), cold stratification (St), and dry afterripening (DA) pretreatments. Seeds occupying a volume of 15.25 in^3 (250 cm^3) were scarified for 20 seconds in a

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Forsberg scarifier at 1725 r/min. For washing, seeds occupying a volume of 12.20 in^3 (200 cm^3) were placed in a 20.34 oz (600 ml) beaker, covered with cheesecloth and exposed to continually flowing tap water (43° F (6° C); flow rate of 1.19-1.36 oz (35-40 ml) per sec) for 24 hours. Washed seeds were then air dried 70° F (21° C) for 24 hours to facilitate handling. Cold stratification involved maintaining imbibed seeds on germination blotter at 36° F (2° C) for 3 or 4 weeks. The sequence of application of combination treatments (Sc+W, Sc+St, W+St, and Sc+W+St) is shown in figure 1. To determine effects of DA, seeds were evaluated at various postharvest dates.

Blotter Germination Conditions

Pretreated seeds were germinated in a germinator cycling at 75° F (24° C) for 16 hours of light, and 55° F (13° C) for 8 hours of darkness. Each treatment was replicated six times. Each replication consisted of 100 seeds on one sheet of heavy blotter contained in a 4 by 5 by 1 in (10 by 10 by 2.5 cm) plastic box with a tightly fitting lid, with an initial application of 0.34 oz

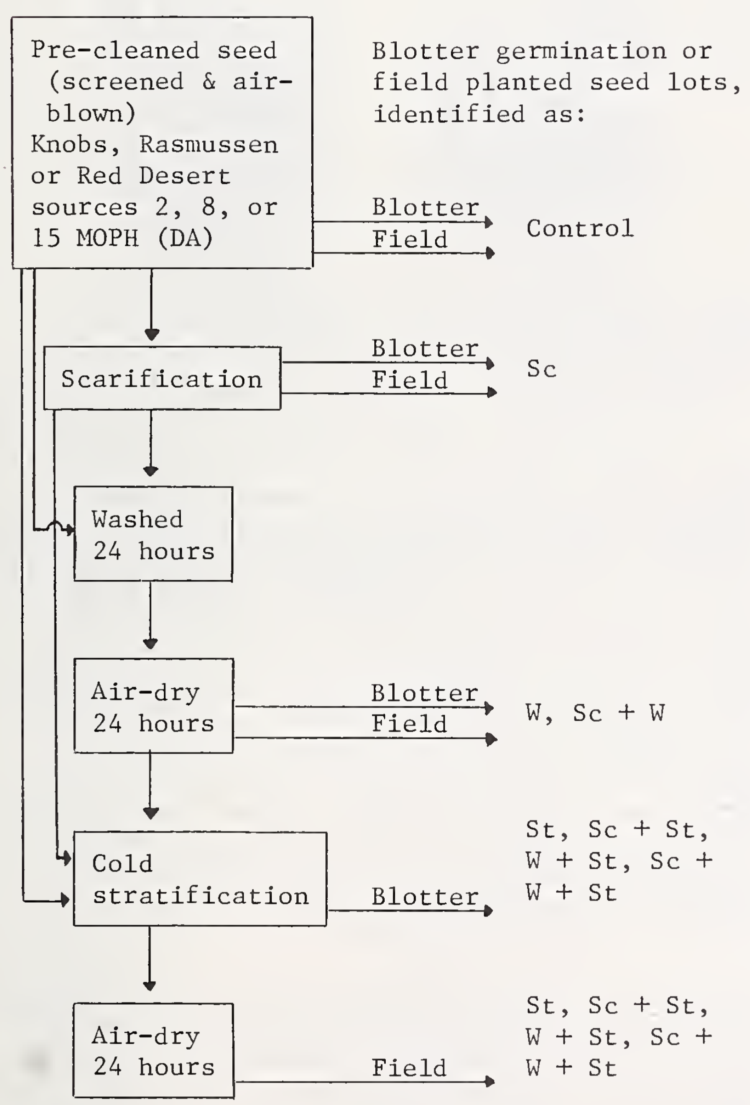

Figure 1.--Seed pretreatment application flowchart.

(10 ml) distilled water. Seeds which were stratified (either as a single treatment or in combination with others) were transferred directly to the germinator while in the hydrated condition following stratification. Other pretreatments were air dried (fig. 1).

Seeds from all three sources were evaluated on germination blotter. Germination, as indicated by 0.6 in (15 mm) radicle extension, was assessed at 3, 5, 10, 15, 25, 35, and 45 days.

The term "germination" in this study refers only to those events preceding and ending with radicle emergence from the testa. "Seedling vigor" refers to postgermination emergence from soil and subsequent establishment. Cotyledon or perisperm reserve utilization is considered a post-germination event and is thus an aspect of seedling vigor (Bewley and Black 1982).

Field Emergence Study

Eight- to ten-month postharvest (MOPH) 'Red Desert' seeds collected in August 1981 were used for the field study. Seeds were pretreated and spring planted at three different sites in Wyoming:

(1) On April 7 and again on April 27, at a topsoiled coal mine reclamation site operated by Bridger Coal Co., 19 mi (30 km) west of Wamsutter;

(2) On April 28, at a topsoiled bentonite mine reclamation site operated by Wyo-Ben, Inc. 7.5 mi (12 km) east of Thermopolis; and

(3) On June 9, at University of Wyoming research plots in Laramie.

Pretreatments (Sc, W, St) were arranged in a completely randomized 2X2X2 factorial. A single row cone seeder with a knife furrow opener was used for seeding. The seeder requires dry seed. Therefore, all seeds which were washed or stratified, or had washing or stratification as the last of a combination of pretreatments, were air dried at 70-75° F (21-24° C) for 16 to 24 hours prior to seeding.

Each treatment replication consisted of 350 seeds (168 filled seeds) planted at 0.4 in (1 cm) depth (Nord and others 1971; Vories 1981) in a single row 21 ft (6.4 m) long. Treatments were replicated four (April 7) and eight (April 27) times at Bridger, eight times at Thermopolis, and five times at Laramie. Replication number was dependent on the size constraints of each site. Seedlings were counted periodically at each site from June to September 1982. Seedlings were considered emerged when the first pair of non-cotyledon leaves were observed.

To observe emergence under dryland conditions, the reclamation sites were not irrigated before or after seeding. Both sites were seeded in April to maximize use of soil moisture accumulated during winter. The Thermopolis site was fenced to exclude sheep and deer which are prevalent in the area. The Bridger site was unfenced. It was assumed mining activity less than 980 ft (300 m) from the research site would preclude large herbivores from grazing on the site. Rodents and other small herbivores as well as weeds were not controlled at either of the reclamation sites.

To observe emergence under conditions which might be considered least-limiting, the Laramie site was seeded in early June to avoid colder early spring soil temperatures. Four-tenths in (1 cm) of water was sprinkler applied every 5 days for the first 30 days following seeding. Moreover, large herbivores, rodents, and weeds were excluded.

Concurrent with the field study, 8 MOPH 'Red Desert' 1981 seeds were similarly pretreated and laboratory blotter germinated. Effects of 24 hours air drying (70° F/21° C) following stratification on blotter germination were observed to simulate pretreatment conditions encountered prior to planting during the field study.

Data Analysis

Total cumulative germination (based on percent of filled seed) and germination rate data were obtained in the laboratory tests. Germination rates were evaluated by calculating the mean time in days taken for nondormant viable seeds to germinate, as discussed by Ellis and Roberts (1978). The mean germination time (MGT) was calculated as follows:

$$MGT = \frac{\Sigma(Dn)}{\Sigma n}$$

where D is the number of days from the beginning of the germination assay and n is the number of seeds germinating on day D. The mean germination time determined by this equation is corrected for differences in final germination percentage.

Field emergence was based on the total seedling counts taken in September 1982 and expressed as a percent of filled seed. Data from laboratory and field studies were subjected to analysis of variance procedures. The LSD and Duncan's Multiple Range Test ($P \leq 0.05$) were used for mean comparison.

RESULTS AND DISCUSSION

Pretreatment Effects on Laboratory Germination

Blotter germination of 2 and 15 months postharvest (MOPH) 'Knobs' 1980 seed is shown in figure 2. Seed fill of this population was determined to be 60 percent. In 2 MOPH seed, stratification (St), and washing + stratification (W+St) enhanced germination in nonscarified seeds. In scarified seeds, W+St was effective but St alone was not. Washing alone was not effective in intact or scarified seeds. Washing + St in scarified seed yielded the greatest germination, but this was still only 50 percent of filled seeds. Viability tests from a previous experiment determined that in each of the Gardner saltbush seed populations studied, 85 to 95 percent of the filled seeds were viable (Ansley 1983). Thus, no pretreatment completely removed dormancy at 2 MOPH.

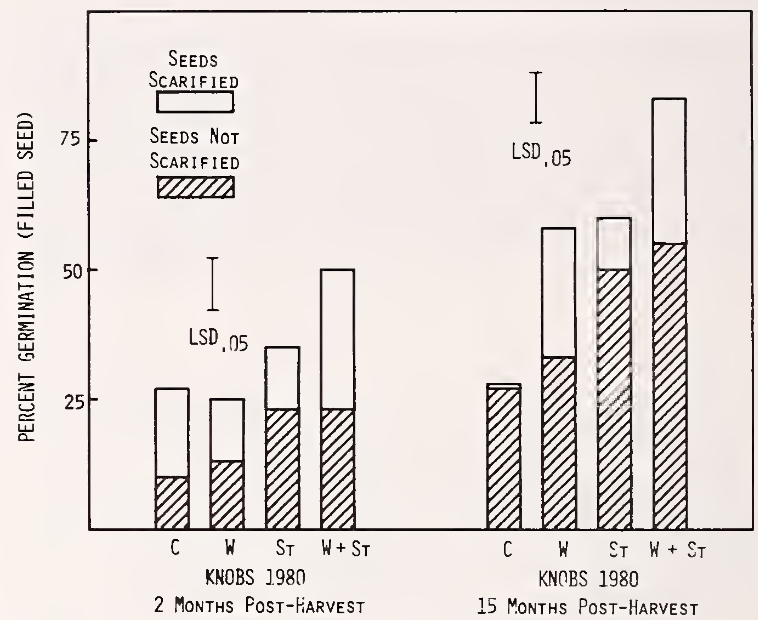

Figure 2.--Effects of 24 hours washing (W), 4 weeks stratification (St), and dry afterripening on blotter germination of scarified and intact 'Knobs' 1980 Gardner saltbush seeds.

Germination was greater in 15 MOPH than 2 MOPH 'Knobs' 1980 seed for all treatments except the scarified control (fig. 2). These responses indicate a dry afterripening (DA) effect. Washing was effective in scarified 15 MOPH seed but was not effective in intact seeds. Physiologically, this may indicate that embryo rather than exterior germination inhibiting substances were leached out to overcome dormancy. Stratification enhanced germination nearly equally in both scarified and intact 15 MOPH seeds. This suggests that effects of St were independent of the coat and, therefore, may have been operating on the embryo. Washing + St of scarified seed yielded the greatest germination with almost a complete removal of dormancy.

In addition to embryo dormancy, the 'Knobs' 1980 source may have some seed coat-imposed dormancy. It is well documented that bracteoles and/or seed coats in many Atriplex spp. contain salts and/or other compounds which inhibit germination (Beadle 1952, Cornelius and Hylton 1969, Osmond and others 1980). While leaching of nonscarified

seed did not enhance germination of the 'Knobs' 1980 seed source at either postharvest date, scarification alone increased germination significantly in 2 MOPH seed (fig. 2). However, this effect was not seen in 15 MOPH seed of the 'Knobs' 1980 source. This suggests that DA may induce a release from whatever coat-imposed dormancy exists in the early postharvest stages of Gardner saltbush seeds.

Similar trends in response to Sc, W, and St pretreatments were seen with 'Knobs' seed collected the following year (1981) and on seed collected in 1980 from the Rasmussen source, which is about 31 mi (50 km) west of the Knobs site (fig. 3). Both of these seed populations were 15 MOPH

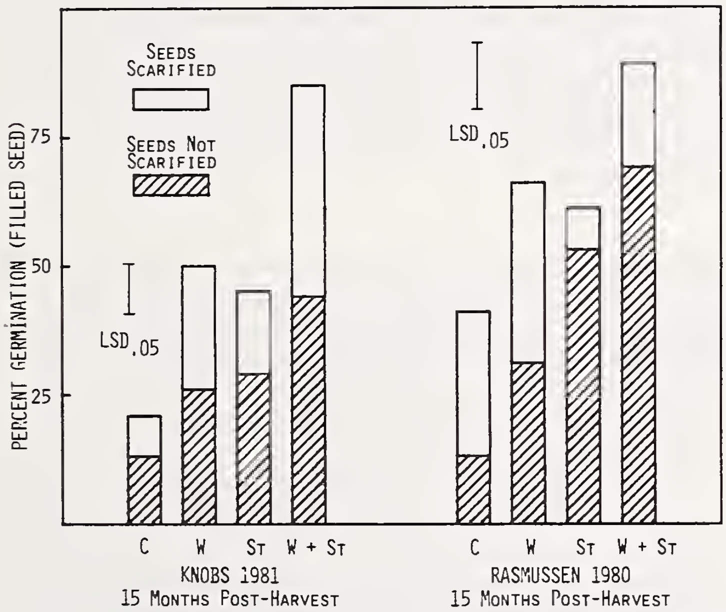

Figure 3.--Effects of 24 hours washing (W) and 4 weeks stratification (St) on blotter germination of scarified and intact 'Knobs' 1981 and 'Rasmussen' 1980 seeds at 15 months postharvest.

at the time of pretreatment application and can be compared directly to 15 MOPH 'Knobs' 1980 results in figure 1. Sc+W+St yielded the greatest germination in seeds from all three sources. Interestingly, response of 'Knobs' seed to St as a single treatment was significantly less relative to other pretreatments in 1981 seed than 1980 seed. 'Rasmussen' showed a much greater sensitivity to scarification than both 'Knobs' 1980 and 1981 seed. Moreover, effects of W on intact seeds were significant in 'Rasmussen' but not in 'Knobs' (fig. 2 and 3). This suggests that 'Rasmussen' seed has a greater degree of coat-imposed dormancy than 'Knobs' seed. Thus, seed source may affect both type of dormancy and dormancy alleviation requirements in Gardner saltbush. This response could be related to the environment of the parent plants during seed maturation, to the genotype of the parent plants, or both. This has yet to be resolved.

Seed pretreatments markedly affected germination rates as well as total germination in all three seed populations. The mean times to germination (MGT) shown in table 1 generally decrease in the order the pretreatments are listed. For all seed sources the shortest MGT (highest germination rate) was obtained by the combination of Sc+W+St. The longest MGT was dependent on source. Stratification was the single pretreatment having the greatest effect on germination rate, and stratification in combination with other pretreatments generally reduced the MGT.

The standard errors for MGT's included in table 1 indicate that as the MGT was reduced by pretreatments the uniformity of germination over time within a pretreatment was increased. This is the response sought for agronomic crops, and it may have implications for the land reclamation specialist seeding Gardner saltbush. Using various combinations of the pretreatments described in this study, it was possible to adjust, to some degree, the level of seed dormancy remaining

Table 1.--Mean time to germination (MGT) in days for Gardner saltbush seed sources following application of pregermination treatments.

Pretreatment	Seed source: Knobs 1980 2 MOPH	Knobs 1980 15 MOPH	Knobs 1981 15 MOPH	Rasmussen 1980 15 MOPH
Control	[1]18.1 (3.4)	14.6 (1.0)	17.9 (2.5)	26.6 (1.7)
Washed	24.2 (2.9)	14.0 (1.5)	14.0 (1.3)	22.0 (1.5)
Scarified	13.6 (1.9)	13.0 (1.2)	16.3 (1.1)	30.1 (2.7)
Scarified + washed	16.4 (0.7)	10.5 (0.4)	12.7 (0.6)	16.8 (0.8)
Scarified + stratified	11.0 (0.5)	4.8 (0.5)	9.5 (0.9)	9.9 (0.8)
Washed + stratified	13.5 (1.2)	4.2 (0.3)	8.0 (0.7)	9.2 (0.6)
Stratified	12.3 (0.8)	4.1 (0.3)	10.9 (0.4)	8.1 (0.7)
Scarified + washed + stratified	9.9 (1.0)	3.9 (0.1)	6.4 (1.0)	7.7 (0.6)

[1]Mean time in days and (standard error).

in a seed source and the rate and uniformity of germination. The implication of this is that when the reclamation site is to be irrigated or is likely to receive ample precipitation and the site is otherwise favorable, it may be advantageous to use seed pretreated to achieve rapid and uniform germination. Under less favorable and/or predictable seeding conditions, it may well be advantageous to use pretreatments allowing a portion of the seed to remain dormant.

Field Emergence

Eight MOPH 'Red Desert' 1981 seeds were used for all field emergence studies. Seeds were stratified 3 rather than 4 weeks prior to field planting because it was determined that a significant number of dry afterripened 'Knobs' and 'Rasmussen' seeds had germinated after 4 weeks of stratification. Seeds with radicles protruding would not survive the planting operation. Limiting the stratification treatment period to 3 weeks did reduce the blotter germination percentage somewhat relative to that obtained in the other seed sources which were stratified for 4 weeks (fig. 2 to 4).

It was determined that air drying of stratified seeds did not adversely affect the enhancement effect of St on blotter germination, except for a slight decline in scarified seeds treated with W+St (fig. 4).

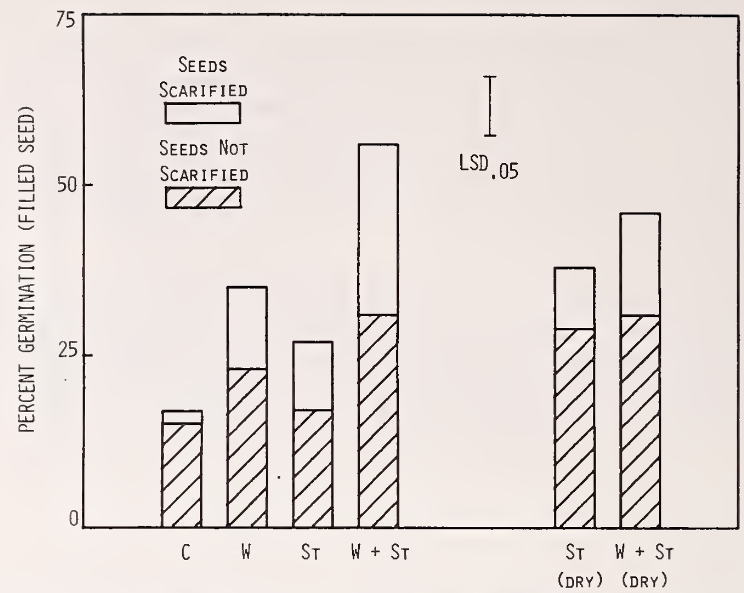

Figure 4.--Effects of 24 hours washing (W) and 3 weeks stratification (St) without and with a 24 hour air-drying (Dry) period prior to assay of blotter germination of scarified and intact 8-month postharvest 'Red Desert' 1981 Gardner saltbush seeds.

For all seed pretreatments blotter germination was substantially higher than field emergence, including the Laramie site where conditions were considered least limiting (fig. 4 and table 2).

Table 2.--Effects of seed pretreatments on field emergence of 8 month postharvest 'Red Desert' 1981 Gardner saltbush seeds at two dryland reclamation sites (Bridger and Thermopolis) and one irrigated site (Laramie).

	Percent emergence (filled seed)[1]			
	Bridger dryland		Thermopolis dryland	Laramie irrigated
Pretreatment[2]	April 7	April 27	April 28	June 9
1. Control	0 a	1 a	1.2 d	1.0 d
2. Scarified	1 a	1 a	2.9 bcd	2.0 cd
3. Washed	1 a	0 a	1.6 cd	1.4 d
4. Scarified + washed	1 a	1 a	2.3 cd	3.8 cd
5. Stratified	1 a	0 a	3.1 bc	9.2 b
6. Scarified + stratified	1 a	1 a	5.2 a	16.7 a
7. Washed + stratified	1 a	1 a	3.0 bcd	8.6 b
8. Scarified + washed + stratified	1 a	1 a	4.6 ab	6.0 bc

[1]Each mean based on percent emergence of 168 filled seeds (out of 350 total seeds). Emergence data were obtained 11 to 17 weeks after seeding at all sites.
[2]Treatments: Control = untreated seed, W = 24 hours washing, St = 3 weeks stratification, Sc = scarification.
[3]Means within each column having similar letters are not significantly different at P ≤ 0.05 according to Duncan's New Multiple Range Test.

This suggests that Gardner saltbush seedling vigor is poor and may inhibit establishment from direct seeding in the spring as much as seed dormancy, if not more.

When dormancy was combined with poor seedling vigor, very little establishment occurred at any site. When dormancy was removed, establishment was increased at Thermopolis and Laramie. The number of seedlings that emerged at Bridger was so low that conclusions regarding effects of pretreatments on field emergence were tenuous. At Laramie Sc+St yielded the greatest emergence (table 2). This differs from blotter germination results which indicated that Sc+W+St was the most effective pretreatment.

Washing was shown in a previous study (Ansley 1983) to remove over 11 percent of the ovendry material in both scarified and intact Gardner saltbush seeds. Apparently, loss of this material, combined with the dry weight loss due to scarification (18 percent), did not inhibit blotter germination but may have adversely affected seedling vigor and subsequent field emergence.

CONCLUSIONS

Ecologically, treatments were selected for this study which reflected conditions in the natural environment which might overcome seed dormancy in Gardner saltbush. In the cold, windy, and arid environment of the Red Desert Basin, seeds could potentially be exposed to all the pretreatments (scarification, dry afterripening, washing, stratification) artificially created in this study. Moreover, species which have evolved in harsh climates often have complex seed dormancies which may involve the interaction of several environmental factors to break dormancy. This appears to be so for Gardner saltbush.

In summary, Sc, W, St, and DA individually increased laboratory blotter germination of several populations of Gardner saltbush seeds to varying degrees. However, complete dormancy removal did not occur until the seed was exposed to all four pretreatments.

The pretreatments were economical and easy to apply to the seeds. Pretreating seeds to overcome dormancy served as an effective strategy for increasing establishment of Gardner saltbush via direct seeding on two of three sites evaluated. The combination of Sc+St yielded the greatest field emergence. Washing, while promoting blotter germination, appeared to inhibit field emergence of scarified and stratified (Sc+St) seeds. These results suggest that care must be exercised in using laboratory germination results to predict the potential field performance of a seed lot. Laboratory germination and field establishment responses to specific treatments may not always be identical. Seedling vigor was quite poor in this species and substantially reduced establishment success even when growing conditions were least-limiting and seed dormancy was alleviated.

PUBLICATIONS CITED

Ansley, R. James. Dormancy, germination, emergence, and ecology of Gardner saltbush (Atriplex gardneri (Moq.) D. Dietr.) seeds. Laramie: University of Wyoming; 1983. 116 p. Ph.D. dissertation.

Beadle, N. C. W. Studies in halophytes. 1. The germination of the seed and establishment of the seedlings of five species of Atriplex in Australia. Ecology. 33(1): 49-62; 1952.

Becker, C. F.; Alyea, J. D. Temperature probabilities in Wyoming. Bull. 415. Laramie, WY: University of Wyoming Agriculture Experiment Station; 1964. 157 p.

Bewley, J. D.; Black, M. Physiology and biochemistry of seeds in relation to germination. 2. Viability, dormancy and environmental control. New York; Springer-Verlag; 1982. 375 p.

Bleak, A. T.; Frischknecht, N. C.; Plummer, A. P.; Eckert, Jr., R. E. Problems in artificial and natural revegetation of the arid shadscale vegetation zone of Utah and Nevada. J. Range Manage. 18(2): 59-63; 1965.

Cornelius, Donald R.; Hylton, Lynn O. Influence of temperature and leachate on germination of Atriplex polycarpa. Agron. J. 61: 209-211; 1969.

DePuit, E. J.; Coenenberg, J. G. Establishment of diverse native plant communities on coal surface-mined lands in Montana as influenced by seeding method, mixture and rate. Res. Pap. 163. Bozeman, MT: Montana State University, Agriculture Experiment Station; 1980. 64 p.

Ellis, R. H.; Roberts, E. H. Towards a rational basis for testing seed quality. In: Hebblethwaite, P. D., ed. Seed production. London: Butterworths; 1978: 605-635.

Malcolm, C. V. Establishing shrubs in saline environments. In: McKell, C. M., ed. Wildland shrubs - the biology and utilization. Gen. Tech. Rep. INT-1. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 1972: 392-404.

McKell, C. M. Selection, propagation and field establishment of native plant species on disturbed arid lands. Bull. 500. Logan, UT: Utah State University Agriculture Experiment Station; 1979. 49 p.

Nord, E. C.; Hartless, P. F.; Nettleton, W. D. Effects of several factors in saltbush establishment in California. J. Range Manage. 24(3): 216-223; 1971.

Osmond, C. B.; Bjorkman, O.; Anderson, D. J. Physiological processes in plant ecology toward a synthesis with Atriplex. New York: Springer-Verlag; 1980. 468 p.

Stubbendieck, J.; Hatch, S. L.; Kjar, K. J. North American range plants. Lincoln, NB: Nat. Resources Enterprises, Inc.; 1981. 468 p.

Van Epps, G. A.; McKell, C. M. Revegetation of disturbed sites in the salt desert range of the intermountain west. Land Rehab. Series No. 5. Logan, UT: Utah State University Agriculture Experiment Station; 1980.

Vories, K. Growing Colorado plants from seed: A state of the art. Vol. 1: Shrubs. Gen. Tech. Rep. INT-103. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1981. 80 p.

Young, J. A.; Evans, R. A.; Kay, B. L.; Owen, R. E.; Jurak, F. L. Collecting, processing, and germinating seeds of western wildland plants. ARM-W-3. Reno, NV: U.S. Department of Agriculture, Agricultural Research Service; 1978. 38 p.

In: Tiedemann, Arthur R.; McArthur, E. Durant; Stutz, Howard C.; Stevens, Richard; Johnson, Kendall L., compilers. Proceedings--symposium on the biology of Atriplex and related chenopods; 1983 May 2-6; Provo, UT. General Technical Report INT-172. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 309 p.

ECOLOGY OF SEED GERMINATION IN REPRESENTATIVE CHENOPODIACEAE

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ABSTRACT: Seeds of species of the Chenopodiaceae exhibit a variety of germination and dormancy mechanisms. In certain species, germination can be very rapid following the rupture of the pericarp (testa) during imbibition of water. Persistent and sometimes indurate fruiting bracts sometimes induce dormancy by reducing osmotic potentials through accumulation of soluble salts, by limiting transfer of moisture and/or gases to the embryo, or through chemical inhibitors. The production by the same plant of polymorphic forms of seed, often having dramatically different germination characteristics, is a major characteristic of chenopods.

INTRODUCTION

The family Chenopodiaceae includes about 100 genera and possibly 1,400 species (Lawrence 1959). Interest in the ecology of germination of this family is high, because it includes: (a) cosmopolitan weeds, (b) shrubs native to western North America that are desirable species for revegetation of disturbed wildlands, and (c) species whose natural habitat includes seedbeds with osmotic potentials lowered by accumulations of soluble salts and possibly toxic specific ions. This paper highlights the germination ecology of representative native chenopod shrubs, especially those that are species of _Atriplex_. Unfortunately, with a few exceptions, there is much more germination literature devoted to weedy chenopods and extreme halophytes than to shrubs suitable for revegetation of wildlands. Individual scientists and managers interested in the seedbed ecology of shrubby species of _Atriplex_ have a considerable amount of related germination literature that can be extrapolated to these species. Little specific information exists.

Morphology of Pistillate Fruits

The fruit of the chenopod is usually a one-seeded, thin-walled utricle. The walls of the utricle can become quite complex. In the case of the _Atriplex_ species, more or less foliaceous bracts that surround the pistillate flowers become enlarged and even inflated. These bracts, in some instances, are deposition sites for soluble salts separated by the metabolic processes of the plants, which help to maintain osmotic equilibrium. These accumulated salts can be a major factor in influencing germination characteristics of chenopod seeds.

The members of the Chenopodiaceae family are often classified by characteristics of the embryo. The embryo can be tightly spirally coiled as in the case of _Halogeton_ or _Salsola_ or annular (ring-shaped or conduplicate) as in the case of _Atriplex_ species. There are exceptions to all generalizations, and in some chenopods such as _Beta_ the ovary is sunk into the succulent base of the calyx which at maturity forms an irregular, indurate ball.

GERMINATION OF WIDELY DISTRIBUTED ANNUAL CHENOPODS

Chenopodium album L.

This comopolitan weed is a pest in so many agricultural situations that its germination ecology has attracted considerable attention. Any review of the literature on germination of _C. album_ seeds will produce many apparent conflicts. Seeds are light sensitive in an apparent phytochrome relationship (Cumming 1963). Seeds require nitrate or nitrate and chilling for germination (Henson 1970). Germination of _C. album_ seeds can be enhanced by removing the enclosing fruit coat (Chu and others 1978). Williams and Harper (1965) determined that seeds of _C. album_ are polymorphic. The seeds vary in size, color, and surface texture, even in samples from single plants. Three distinct germination responses to cold and nitrate were observed by Williams and Harper (1965). Brown seeds germinate quickly as soon as they are provided with water, even at temperatures as low as 32°F (0°C). Black-reticulate seed dormancy is broken by nitrate, but not by chilling. Black-smooth seed dormancy is broken by nitrate, but is partly replaceable by chilling. The three categories of seed, which may be obtained from one parent, may differ as much in requirements for germination as many species differ from each other.

The seed polymorphism present in _C. album_ is phenotypic. The proportions of the polymorphic categories are not greatly influenced by treatments such as nitrogen fertilization although these greatly modify growth, life cycle, and reproductive output of the species. Williams and Harper (1965) determined that brown seeds, the highly germinable form, are usually the first to mature. Cumming (1959) presents evidence that the production of brown seed by _C. album_ plants may be controlled by photoperiod.

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Chenopodium bonus-henricus L.

The germination of seeds of this species has been widely investigated because of the rather unique characteristics of the seeds. The excised embryos of C. bonus-henricus will germinate when given proper incubation. The fruit coat is thought to contain polyphenol compounds that interfere with oxygen transfer to the embryo (Dorne 1981). Seeds from plants grown at higher elevations exhibit greater inhibition of germination. This is contrary to the phenotypic forms of dormancy in C. album, which occur more or less independently of maternal environmental stimuli, except for day length.

The light requirement for germination of C. bonus-henricus seeds can be substituted for by prechilling (Khan and Karson 1981). This light requirement can be reinstated by prolonged, dark imbibition in low osmotic potential solutions. However, prolonged exposure to radiation of chilled seeds under these conditions prevents dormancy and hastens subsequent germination in light or in darkness (Khan and Karson 1980).

Halogeton glomeratus C.A. Mey

Halogeton glomeratus was accidentally introduced to the salt-desert and lower Artemisia rangelands of western North America. One of the first observations of seed ecology of H. glomeratus was the discovery of black and brown seeds (Tisdale and Zappettini 1953). Black seeds were found to be highly germinable immediately after seed cast while brown seeds were almost entirely dormant in laboratory trials.

Black seeds of H. glomeratus placed on moist filter paper absorb water so rapidly that the ovary wall may rupture and expel the embryo within an hour (Williams 1960). The embryos of black seeds uncoil at once and frequently can be planted within 9 to 10 hours. The embryos of brown seeds only swell slightly when placed on moist filter paper and appear unable to penetrate the protective ovary walls. Excised embryos from brown seeds rarely uncoil within 48 hours. When they uncoil, a green pigment appears in the cotyledons. The embryos of black seeds contain chlorophyll before emergence.

Williams (1960) discovered that in black seeds of H. glomeratus the major portion of resources is stored as sucrose, while storage in brown seeds is starch. Williams also showed that production of the dormant brown seeds is controlled by photoperiod. The brown or dormant form of H. glomeratus seeds is produced first, under long-day photoperiods. The germinable or black seed is produced later, under shorter photoperiods. Late germinating and flowering plants produce only black seeds.

Salsola iberica Sennen and Pau and S. paulsenii Litv.

Salsola iberica and S. paulsenii are alien species widely distributed on Intermountain rangelands in disturbed areas. The plant morphology of both species can be highly variable in terms of size, shape, and color. Despite these observed differences, seed polymorphism does not appear to be prevalent.

Salsola iberica produces a large number of seeds with spirally coiled embryos in a very thin, papery fruit. The fruits are tightly held in axillary bracts and often released only when the plants break off at the soil surface and are tumbled by the wind (Evans and Young 1982). Salsola is not highly competitive with other annuals. A well-developed dispersal system and superabundant seed production help to ensure that some seeds reach freshly disturbed areas.

Seedlings of Salsola in western North America are not particularly frost tolerant. Germination is severely restricted in the fall by temperature-related afterripening requirements (Evans and Young 1982). Gradually over the winter these requirements break down; by late spring the seeds of these species germinate at virtually any seedbed temperature from 28° to 113°F (-2° to 45°C) including diurnal fluctuations of these extreme temperatures. Germination response is controlled internally and is relatively free of external stimuli.

Although the two species of Salsola have similar germination requirements, the afterripening requirements for seeds of S. paulsenii are slightly less restrictive, imparting an apparent competitive advantage in desert situations (Evans and Young 1982).

Atriplex patula ssp. hastata (L.) Hall and Clem.

Seeds of this species do not require light for germination but light enhances germination (Young and others 1981). With light during incubation, germination at optimum temperatures averages 96 percent.

Although seed dimorphism is not readily apparent, different size seeds produce markedly different rates of seedling growth (Baker 1972).

GERMINATION OF SEEDS OF SEMIWOODY CHENOPODS

This is a rather artificial grouping that can be further qualified by limiting it to species that generally occur in almost pure stands over limited areas. These chenopods also happen to be highly desirable browse species. This category includes selected species in the genera Kochia, Ceratoides, and a restricted section of Atriplex. The seeds of these species appear to have highest germination at or very near the surface of seedbeds. The storage life of these seeds is variable and can be quite short.

Ceratoides lanata (Pursh) J.T. Howell

H. W. Springfield spent several years studying the seed ecology of C. lanata. He concluded that for optimum germination a period of afterripening was required (Springfield 1968). Germination of C. lanata seeds was influenced by seedbed temperature and moisture stress (Springfield 1968). Optimum germination occurred at relatively warm incubation temperatures of 77° to 80°F (25° to 27°C) and exceeded 90 percent germination over a wide range of temperatures 50° to 80°F (10° to 27°C) (Springfield 1972b). Springfield (1972) did not find the wide range of polymorphic forms that characterize some of the annual chenopods, but he did determine a wide size range in the seeds of C. lanata and that large seeds had higher germination percentages.

When the germination rates of different collections of C. lanata seeds are compared in relation to temperature or moisture stress, considerable ecotypic variability is apparent (Workman and West 1967; Clark and West 1971). This ecotypic variability has probably contributed to conflicting reports on seed germination of this species and maybe to the variable results obtained in attempts to revegetate rangelands with C. lanata.

Kochia prostrata (L.) Schrad.

This species is native to central Asia and eastern Europe where it is a highly variable, but often valuable, forage plant. It has been imported to the Intermountain area for use in revegetation of range sites including degraded Ceratoides lanata and Kochia americana Wats. communities.

The seeds of K. prostrata uncoil very rapidly at a wide range of temperatures, but true growth, as indicated by raising the hypocotyl arch, occurs in a much more restricted temperature range (Young and others 1981).

Major problems with the use of K. prostrata in revegetation of grazing lands in central Asia have been the short half-life of the seeds in storage and the lack of frost tolerance by seedlings (Nechaeva and others 1977). The storage of small lots of seeds of K. prostrata has not been a problem in the United States (Young and others 1981). (See Jorgensen and Davis, this proceedings, for techniques to handle large volumes of K. prostrata seed.)

Atriplex nuttallii Wats.

This is an extremely diverse phylogenetic group which, depending on the authority, can include the taxa A. gardneri (Moq.) and A. cuneata A. Nels. (See R. J. Ansley and R. H. Abernethy, this proceedings, for germination ecology of A. gardneri). Not only are the members of this group morphologically diverse, but they also occupy a wide variety of environments especially in relation to the soluble salt content of soils (Goodman 1973).

The common threads that more or less characterize this group of semiwoody chenopods appear to be: (a) a great deal of variability, attributed to genotypic rather than phenotypic sources; (b) a high degree of phenotypic polymorphism in seeds; (c) very rapid germination under ideal situations; (d) poor emergence from burial in seedbeds, with surface seeding the most desirable; and (e) short and highly variable seed storage half-life.

GERMINATION OF WOODY SPECIES OF CHENOPODS

The University of California was experimenting with establishing species of Atriplex on grazing land by seeding in 1882 (Jaffa 1899). The Australians have a long history of research on the germination of Atriplex species, highlighted by the classic paper of Beadle (1952). For most of the woody species of chenopods, the embryo is usually borne in fruit that may include complex bracts.

Beadle (1952) described how the seeds of some of the major species of Atriplex in Australia were shed from the plant enclosed in bracteoles. These bracteoles persisted for variable lengths of times until they decayed or were removed by abrasion. For some species, the bracteoles persisted until long after the seeds had lost their viability. When enclosed in the bracts, the seeds germinate only after relatively long periods of moist incubation. Beadle, as had Wood in 1925, attributed this retardation to high concentrations of chloride ions in the fruiting structure.

Beadle (1952) also determined that the seeds of some species of Atriplex did not readily imbibe water. Seeds in populations that had hard seed coats or impermeable testa were highly variable in their ability to imbibe water.

Atriplex canescens (Pursh) Nutt.

The germination of this species has been extensively studied by H. W. Springfield (1970). Maximum germination occurred at moderate incubation temperatures, from 55° to 75°F (13° to 24°C). A. canescens seeds did not respond to the presence or absence of light during incubation. Removal of most of the persistent bracts with a hammer mill speeded up germination, but did not markedly increase 28-day germination levels.

Springfield (1970) found a great deal of variability in the seed coat of A. canescens within and among collections. The seeds of some sources exhibited increased germination with scarification while seeds of other sources showed a marked decrease in germination when scarified.

Eamor Nord also spent considerable time studying the germination and seedbed ecology of A. canescens. He believed there was a saponin-like substance in the bracts that inhibited germination (Nord and VanAtta 1960). Twitchell (1955) enhanced the germination of A. canescens seeds by soaking, but attributed the enhancement to the removal of chlorine.

Despite the assumption that the bracts of A. canescens seeds contained germination inhibitors, Nord also experimented with scarification (Nord and VanAtta 1957). The results of these studies were rather inconclusive.

The much lower germination of filled seeds in tetraploid A. canescens than in diploid plants of A. canescens exemplifies genetic control of dormancy systems (Stutz and others 1976).

Graves and others (1974) found that mechanical scarification of A. canescens was the only treatment that markedly increased 7-day germination rates. It only slightly enhanced the 14-day germination level over the fairly high germination level of the control seeds. Both Graves and others (1974) and Springfield (1970) determined that hot water soaking completely inhibited the germination of A. canescens seeds.

Atriplex polycarpa (Torr.) Wats.

The seeds of A. polycarpa have reduced germination when incubated in the presence of leachate from the utricle (Chatterton 1970; Cornelius and Hylton 1969; Askham and Cornelius 1971). Light is not required for germination of seeds. Graves and others (1974) found that seed size of A. polycarpa markedly influenced germination; large utricles germinated significantly ($P = 0.05$) better than smaller sizes. This size difference could be an influence of the maternal environment or it could be a phenotypic or genotypic expression of polymorphism. Considering the salt-affected soils where many species of Atriplex are found naturally, specific ion toxicity must play a role in the germination ecology of many species (Chatterton and McKell 1969a&b).

Atriplex semibaccata R. Br.

This native to Australia is naturalized in California and southern Nevada. The seeds of A. semibaccata are quite germinable without pretreatment (Young and others 1981). Germination is enhanced by presoaking and wringing the soak water from the fruits. Seeds do not require light for germination.

Atriplex lentiformis (Torr.) Wats.

The seeds of this North American native are quite germinable without pretreatment. A. lentiformis is similar in germination response to A. semibaccata. Light apparently does not play a role in germination. Presoaking does enhance germination (Young and others 1981).

Atriplex confertifolia (Torr. and Frem.) Wats.

The seeds of this landscape-characterizing species of the Intermountain area are generally highly dormant. Considering the rapid evolution of this group in the pluvial lake environment (Stutz 1978), it would appear reasonable that a great deal of ecotypic variability would occur in germination ecology. Overriding dormancy has precluded discovery of appreciable information on the germination of seeds of A. confertifolia. (See D. C. Warren, this proceedings, for a more comprehensive study.) Prolonged outdoor stratification will produce erratic germination.[1]

Atriplex dimorphostegia Kar. et Kir.

Germination of the dimorphic forms of flat and humped seeds of A. dimorphostegia was promoted by short-duration radiation and inhibited by continuous radiation from the same white light source. Germination level was low when in total darkness (Koller 1970). This dual action of light produced an apparent short-day photoperiodic response. Progressive increases in the daily photoperiod caused progressive decreases in germination rate and percentage. The humped seeds were more sensitive to light inhibition (Keller 1957).

Atriplex repanda Phil.

A. repanda is a valuable browse species in the arid portions of Chile (Lailhacar-Kind and Laude 1975). Revegetation with this species has been limited by seed dormancy. Dormancy is apparently imposed by the persistent bracts and a layer that Lailhacar-Kind and Laude (1975) identified as the testa. The bracts are so indurate that mechanical scarification often damages the embryo.

Fernandez, Myrma, and Johnston (Fernandez and Myrma 1978; Johnston and Fernandez 1978) have conducted detailed studies of the germination ecology of this species.

[1]Unpublished data on file with the Agriculture Research Service, Reno, Nev.

Grayia spinosa (Hook.) Moq.

The seeds of G. spinosa are readily germinable without pretreatment (Wood and others 1976). The rapid rate of germination permitted establishment on soils that were dried from field capacity to low matric potentials. The persistent fruiting bracts apparently serve to modify the harsh environment on the surface of seedbeds and aid in germination.

Sarcobatus vermiculatus (Hook.) Torr.

Eddleman (1979) determined that when the membranous pericarp of the S. vermiculatus seed was ruptured, the embryo uncoiled in less than an hour and root hairs developed within 24 hours. With the pericarp intact, rapid imbibition occurred, but germination was slow and many seeds had not germinated after 30 days. The seeds Eddleman tested had increased germination at warm temperatures after cold-moist stratification.

The seeds Eddleman (1979) used in his experiments were collected in southeastern Montana. Apparently, he removed the enclosing papery bracts before initiating trials. We have determined that the enclosing bracts have a decided influence on germination, especially when incubated in moisture-supplying solutions with reduced osmotic potentials.[2]

GERMINATION OF EXTREME HALOPHYTES

The major question in the germination ecology of extreme halophytes is whether germination can occur at extremely low osmotic potentials or if the potentials must be moderated before even the seeds of adapted species can germinate. Chapman (1960) believed that modification of low osmotic potentials was necessary for germination of species adapted to halophytic situations. Ungar (1962) demonstrated that there is apparent adaptation for germination among halophytes at low osmotic potentials.

Osmotic potentials of solutions vary with temperature so one possibility for compensating for low osmotic potentials is for germination to occur at very low incubation temperatures (Rivers and Weher 1971).

Seeds of Salicornia europaea L. have the chenopod germination characteristic--dimorphism. Large seeds are more salt tolerant than small seeds (Ungar 1979).

[2]Unpublished data on file with the Agriculture Research Service, Reno, Nev.

Dormancy of seeds of Suaeda spp. induced by exposure to low osmotic potentials can be reversed through exogeneous applications of gibberellic acid (Boucand and Ungar 1976). Cytokinic activity in Suaeda seed appeared to be reduced by exposure to low osmotic potentials.

Many of these observations on the germination ecology of extreme halophytes may have application to chenopods in general considering the prevalent salt-affected soils of the Intermountain area.

CONSIDERATIONS FOR FUTURE RESEARCH

The ample evidence of diopolymorphism in the seeds of chenopods makes it essential to consider the occurrence of this germination strategy. Failure to recognize polymorphism probably has produced variability in past germination experiments.

A vital need in understanding the germination ecology of native chenopods is to establish the physical parameters in field seedbeds. Data need to be gathered on temperatures at which germination occurs, and osmotic potentials at the actual time of germination.

A most interesting facet of the germination of chenopods in salt-desert environments is the influence of prolonged soaking of seeds in low osmotic potential solutions at optimal germination temperatures. This phenomenon may be the rule rather than the exception in the ecology of many species of chenopods.

Once dormancy requirements are satisfied, the seeds of many species of chenopod uncoil and develop root hairs extremely rapidly. We need to determine whether this is an adaptation for germination in very transitory environments.

PUBLICATIONS CITED

Askham, R. L.; Cornelius. Influence of desert saltbush on germination. J. Range Manage. 24: 439-442; 1971.

Baker, H. Seed weight in relation to environmental conditions in California. Ecology. 53: 997-1010; 1972.

Beadle, N. C. W. Studies in halophytes. I. The germination of the seed and establishment of the seedlings of five species of Atriplex in Australia. Ecology. 33: 49-62; 1952.

Boucand, J.; Ungar, I. A. Hormonal control of germination under saline conditions of three halophytic taxa in the genus Suaeda. Physiol. Planet. 37: 143-148; 1976.

Chapman, V. J. Salt marshes and salt deserts of the world. New York: Interscience Publishers; 1960. 392 p.

Chatterton, N. J. Physiology ecology of Atriplex polycarpa: Growth, salt tolerance, ion accumulation and soil-plant-water relations. Riverside, CA: University of California; 1970. 120 p. Dissertation.

Chatterton, N. J.; McKell, C. M. Atriplex polycarpa: I. Germination and growth as affected by sodium chloride in water cultures. Agron. J. 61: 448-450; 1969.

Chatterton, N. J.; Mckell, C. M. Atriplex polycarpa: II. Germination and growth as in water cultures containing high levels of boron. Agron. J. 61: 451-453; 1969.

Chu, Chang-Chi; Sweet, R. D.; Ozbun, J. L. Some germination characteristics in common lambs quarter (Chenopodium album). Weed Sci. 26: 255-257; 1978.

Clark, L. D.; West, N. E. Further studies of Eurotia lanata germination in relation to salinity. Southwestern Naturalist. 15: 371-375; 1971.

Cornelius, D. R.; Hylton, L. O. Influence of temperature and leachate on germination of Atriplex polycarpa. Agron. J. 61: 209-211; 1969.

Cumming, B. Extreme sensitivity of germination and photoperiodic reaction in the genus Chenopodium. Nature 184: 1044-1045; 1959.

Cumming, B. C. The dependency of germination on photoperiod light quality and in Chenopodium spp. Can. J. Bot. 41: 1211-1233; 1963.

Dorne, Albert-Jean. Variation in seed germination inhibiting of Chenopodium bonus-henricus in relation to altitude of plant growth. Can. J. Bot. 59: 1893-1901; 1981.

Eddleman, L. E. Germination in black greasewood (Sarcobatus vermiculatus (Hook.)). Northwest Sci. 53: 289-294; 1979.

Evans, R. A.; Young, J. A. Russian thistle and barbwire Russian thistle seed and seedbed ecology. Agric. Res. Results ARR-W-25. Oakland, CA: U.S. Department of Agriculture, Agricultural Research Service; 1982. 39 p.

Fernandez, G. H.; Myrma, J. B. Effeco de la testa en la germinacion de Atriplex repanda Phil I - Entrada de agua a la semilla. OYTON. 36: 97-103; 1978.

Goodman, P. J. Physiological and ecotypic adaptations of plants to salt desert conditions of Utah. J. Ecol. 61: 473-494; 1973.

Graves, Walter; Kay, B. L.; Williams, W. A. Seed-treatment studies of seven Mohave Desert shrubs. Appendix II. Test of seed of Mohave Desert shrubs. Davis, CA: University of California Press; 1974. 34 p.

Henson, I. E. The effects of light, potassium, nitrate, and temperature on the germination of Chenopodium album L. Weed Res. 10: 27-39; 1970.

Jaffa, M. E. Australian saltbushes. Bull. 125. Berkley, CA: University of California Agricultural Experiment Station; 1899. 30 p.

Johnston, J. B.; Fernandez, G. H. Effecto de la testa en la germinacion de Atriplex repanda Phil. II - Determinocien de al intensidad respirateria. OYTON. 26: 103-109; 1978.

Khan, A. A.; Karson, C. M. Induction of secondary dormancy in Chenopodium bonus-henricus L. seeds by osmotic and high temperature treatments and its prevention by light and growth regulators. Plant Physiol. 66: 175-181; 1980.

Khan, A. A.; Karson, C. M. Changes during light and dark osmotic treatment independently modulating germination and ribonucleic acid synthesis in Chenopodium bonus-henricus seeds. Physiol. Planet. 51: 264-276; 1981.

Keller, D. Germination-regulating mechanisms in some desert seeds. IV. Atriplex dimorphostegia Kar. et Kif. Ecology. 38: 1-13; 1957.

Koller, D. Analysis of the dual action of white light on germination of Atriplex dimer phostegia (Chenopodiaceae). Israel J. Bot. 19: 499-516; 1970.

Lailhacar-Kind, S.; Laude, H. M. Improvement of seed germination in Atriplex repanda Phil. J. Range Manage. 28: 491-494; 1975.

Lawrence, G. H. M. Taxonomy of vascular plants. New York: MacMillan; 1959. 823 p.

Nechaeva, N. T.; Shamsatdinon, S.; McKammedon, G. M. Improvement of desert pastures in southcentral Asia. Inst. of Deserts of the Turkman Academy of Science. Moscow: USSR Ministry of Agriculture, All Union Insitute of Astrakhan Sheep Breeding; 1977. 67 p.

Nord, E. C.; VanAtta, G. R. Germination of fourwing saltbush seed improved by scarification and grading. Res. Note 125. Berkeley, CA: U.S. Department of Agriculture, Forest Service; Pacific Southwest Forest and Range Experiment Station; 1957. 5 p.

Nord, E. C.; VanAtta, G. R. Saponin - a seed germination inhibitor. For. Sci. 6: 350-353; 1960.

Rivers, W. G.; Weher, D. J. The influence of salinity and temperature on seed germination in Salicornia bigelouis. Physiol. Planet. 24: 73-75; 1971.

Springfield, H. W. Germination of winterfat seeds under different stresses and temperatures. J. Range Manage. 21: 314-315; 1968.

Springfield, H. W. Germination and establishment of fourwing saltbush in the Southwest. Res. Pap. RM-55. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1970. 48 p.

Springfield, H. W. Winterfat seeds undergo underripening. J. Range Manage. 25: 479-480; 1972.

Springfield, H. W. Optimum temperatures for germination of winterfat. J. Range Manage. 25: 69-70; 1972.

Springfield, H. W. Large seeds of winterfat germinate better. J. Range Manage. 26: 153-154; 1972.

Stutz, H. C. Explosive evolution of perennial Atriplex in western America. Great Basin Naturalist Memoirs. 2: 161-168; 1978.

Stutz, H. C.; Pope, C. L.; Leslie, T. Germination studies of Atriplex canescens. In: Proceedings symposium and workshop on wildland shrubs; 1976, Provo, UT: U.S. Department of Agriculture, Forest Service, Shrub Sciences Laboratory; 1976: 150.

Tisdale, E. W.; Zappettini, George. Halogeton studies on Idaho ranges. J. Range Manage. 6: 225-236; 1953.

Twitchell, L. T. Germination of fourwing saltbush seed as affected by soaking and chloride removal. J. Range Manage. 8: 218-220; 1955.

Ungar, I. A. Influence of salinity on seed germination in succulent halophytes. Ecology 43: 763-766; 1962.

Ungar, I. R. Seed dimorphism in Salicornia europea L. Bot. Gaz. 140: 102-108; 1979.

Williams, J. T.; Harper, J. L. Seed polymorphism and germination. I. The influence of nitrates and low temperatures on the germination of Chenopodium album. Weed Res. 5: 141-150; 1965.

Williams, M. C. Biochemical analyses, germination, and production of black and brown seed of Halogeton glomeratus. Weeds 8: 452-461; 1960.

Wood, J. G. The selective absorption of chlorine ions and absorption of water by the leaves of the genus Atriplex. Aust. J. Expt. Biol. and Med. Sci. 2: 45-56; 1925.

Wood, M. K.; Knight, R. W.; Young, J. A. Spiny hopsage germination. J. Range Manage. 29: 53-56; 1976.

Workman, J. P.; West, N. E. Germination of Eurotia lanata in relation to temperature and salinity. Ecology. 48: 659-661; 1967.

Young, J. A.; Evans, R. A.; Stevens, R.; Everett, R. L. Germination of Kochia prostrata seed. Agron. J. 73: 957-961; 1981.

In: Tiedemann, Arthur R.; McArthur, E. Durant; Stutz, Howard C.; Stevens, Richard; Johnson, Kendall L., compilers. Proceedings--symposium on the biology of Atriplex and related chenopods; 1983 May 2-6; Provo, UT. General Technical Report INT-172. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 309 p.

A TECHNIQUE FOR RETAINING SEED VIABILITY IN KOCHIA PROSTRATA [L.] SCHRAD

Kent R. Jorgensen and James N. Davis

ABSTRACT: Germination was greatly increased by lowering seed moisture by ovendrying and outside storage in an airtight container. Four treatments were devised. There was little difference in germination between treatments the first year. Germination with ovendrying/outside storage during the second and third year respectively was 9 and 23.1 percent higher than ovendrying/inside storage, 28 and 45 percent higher than air-drying/outside storage, and 43.6 and 49.4 percent higher than air-drying/inside storage.

INTRODUCTION

There is an increasing interest in 'Immigrant' forage kochia (Kochia prostrata [L.] Schrad) as a desirable half-shrub for revegetation work on our arid and semiarid western ranges. It is highly salt tolerant (Francois 1976), has good forage qualities (Davis 1979), and is a preferred forage for sheep (Menati 1977).

Balyan (1972) found he could maintain higher viability for longer storage periods if moisture content was 6 to 8 percent. He felt seed should be stored at 7 percent moisture in an airtight container to maintain extended viability. Because of the reported loss of viability within 5 to 7 months and high price for the seed (from $16 to $26 per lb or $35 to $57/kg), additional information on seed storage is needed. This study was done to evaluate the effect seed moisture has on seed viability over an extended storage time.

METHODS

'Immigrant' forage kochia seed (P.I. number 314929 - our accession U2) grown at the Snow College Field Station, Ephraim, Utah, was harvested by hand in early November 1979 and allowed to air-dry for 10 days. The seed was then run through a barley debearder to remove seed from the stalks, then through a two-way fan to remove inert material. Seed was stored in 50-lb (23-kg) burlap bags in an open warehouse until February 1980. Two composite samples were removed from the burlap bags. One sample was ovendried at 105° F (40.6° C) for 96 hours, reducing the moisture in the seed to 7 percent, and placed in a vacuum-tight container. A second sample of seed was air-dried to 9.4 percent moisture and placed in a cloth bag where the moisture content could vary with humidity. Control samples with 10.8 percent moisture were taken periodically from seed stored under normal warehouse conditions. Seed samples from the 7 percent and 9.4 percent moisture treatments were divided in two and placed in an open warehouse where the temperature fluctuated from a low of -10° F (-23.3° C) to a high of 75° F (23.8° C), and an office where temperatures ranged from 60° to 80° F (15° to 30° C).

Germination tests were started the first week of March 1980 and continued every 2 weeks until November 1982 when the seed was 3 years old. At the start of each 2-week period, six lots of 100 seeds per treatment were counted; only large plump seeds were used. Seeds were placed between moist paper, then wrapped in plastic and put in a refrigerator where the temperature ranged from 34° F (1.1° C) to 38° F (3.3° C) for 24 hours. Seeds were germinated at room temperature. Counts on germinated seed were made each succeeding day until germination was complete, generally 6 to 7 days. Germination tests were run on the control samples 3, 12, 18, 24, and 36 months after seed harvest. Seed was considered germinated when the hypocotyl length reached 0.2 in (5 mm) (Young and others 1981).

Analysis of variance was used to determine differences in seed germination. Newman-Kuels' multiple means comparison test was used to determine differences between the means.

RESULTS AND DISCUSSION

Both moisture and temperature have a detrimental effect on stored 'Immigrant' forage kochia seed. In table 1, moisture is shown to have a great effect on seed germination, especially when air-dried. During the first year there were no significant differences between inside and outside air-dried seed or inside and outside ovendried seed. There was a significant difference between all treatments

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Table 1.-- Average percent germination for each year of storage.

Years Stored	Air-dried inside storage	Air-dried outside storage	Ovendried inside storage	Ovendried outside storage
1	[1]87.8[a]	85.0[a]	92.6[b]	93.2[b]
2	43.6[a]	54.5[b]	73.5[c]	82.5[d]
3	16.3[a]	20.9[a]	42.6[b]	65.7[c]

[1]Means with the same superscript letter are not significantly (0.5) different.

in the second year. It was also apparent that temperature also had an effect on germination. There was a significant difference within both moisture treatments (air-dried vs. ovendried) with the two different storage temperatures. In the third year there was no significant difference in germination within the air-dried treatment. But the ovendried seed had a significant difference in germination between the two storage temperatures.

We were not able to statistically test our control samples, but germination after the first year was 94.2 percent. It dropped to 9.8 percent the second year. There was no germination the third year.

SUMMARY

Seed from the ovendried/outside storage treatment in an airtight container had the highest overall germination. It went from a high of 93.2 percent the first year to a low of 65.7 percent the third year. We feel that if the seed had been ovendried right after harvesting and cleaned, and kept at a constant 40° F (4.4° C), higher germination through the third year would have been obtained.

PUBLICATIONS CITED

Balyan, G. A. Prostrate summer cypress and its culture in Kirghizia. Washington, DC: U.S. Department of Commerce, National Technical Information Service; 1972. 296 p. Translated from Russian.

Davis, A. M. Forage quality of prostrate kochia compared with three browse species. Agron. J. 71: 822-824; 1979.

Francois, L. E. Salt tolerance of prostrate summer cypress (Kochia prostrata). Agron. J. 68: 455-456; 1976.

Menati, N. Comparative palatability of Atriplex canescens. J. Range Manage. 30: 368-369; 1977.

Young, J. A.; Evans, R. A.; Stevens, R.; Everett, R. L. Germination of Kochia prostrata seed. Agron. J. 73: 957-961; 1981.

In: Tiedemann, Arthur R.; McArthur, E. Durant; Stutz, Howard C.; Stevens, Richard; Johnson, Kendall L., compilers. Proceedings--symposium on the biology of Atriplex and related chenopods; 1983 May 2-6; Provo, UT. General Technical Report INT-172. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 309 p.

PERICARP INHIBITION OF GERMINATION OF ATRIPLEX CONFERTIFOLIA (TORR. & FREM.) WATS.

Daniel C. Warren and Burgess L. Kay

ABSTRACT: Utricles of Atriplex confertifolia (Torr. and Frem.) Wats. offered no germination response when pericarps remained intact. Five pericarp-dependent mechanisms of germination inhibition are proposed and tested. Mechanical resistance offered the best explanation of complete germination inhibition. Osmotic potential and limited oxygen supply only reduced germination. Tannins in the pericarp did not prevent water conduction. Clipping bracts did not enhance germination. Severe hammermill treatment met with little success. Sulfuric acid and legume scarifier treatments produced no seedlings. Seed fill can be detected inexpensively by soaking fruits for 48 hours at 41°F (5°C). Seed within pericarps became apparent under strong light after soaking. No loss of viability occurred during this treatment.

INTRODUCTION

Germination studies on perennial Atriplex species have reported poor germination responses under artificial conditions (Sabo and others 1979; Lailhacar-Kind and Laude 1975). Germination is sometimes hampered by the presence of an indurated pericarp surrounding the seeds. Several mechanisms may be important in explaining the cause of pericarp inhibition, yet few studies exist that explore these mechanisms.

Much attention has been given to Atriplex repanda Phil. with regard to the role of several potential inhibition mechanisms (Fernandez and Johnston 1978; Johnston and Fernandez 1978), but virtually no data exist in the published literature concerning the inhibitive role of the pericarp in the germination of perennial Atriplex species native to the Mojave Desert or the salt-desert regions within the Great Basin. The species native to these locations have tremendous potential as soil cover plants in areas disturbed by off-road vehicle (ORV) use, construction, or mining, and, therefore, a need exists for work in this area.

In the present study, three species native to the Mojave and Great Basin were tested for their germination response after pericarp removal. Atriplex confertifolia (Torr. & Frem.) Wats. germinated 72 percent of the viable seed after pericarp removal. However, intact utricles consistently would not permit germination. Atriplex hymenelytra (Torr.) Wats., having a softer pericarp, germinated at the same rate whether the pericarp was removed or not. Atriplex spinifera Macbr. contained few viable seed and, therefore, did not germinate whether seeds were excised from the pericarp or not.

The pericarps of A. confertifolia are similar to those of the Chilean native, A. repanda; they are extremely indurated, and not abraded, cut or broken easily. Stutz[1] indicated that the pericarp of A. confertifolia created enough mechanical resistance to radicle emergence to inhibit germination. Removal of the pericarps of Atriplex canescens (Pursh.) Nutt. has been shown to hasten germination, demonstrating that inhibition can be removed in some Atriplex species by simply removing the pericarp (Springfield 1970).

The mechanism of inhibition is ill-defined (Leslie and others 1974). With an understanding of the inhibition mechanism, efforts can be made to circumvent it economically. Some researchers have suggested that salt in the pericarp osmotically inhibits germination by inhibiting imbibition (Beadle 1952; Chatterton and McKell 1969; Koller 1957; West 1969). While it can be shown that pericarps contain sodium chloride, leaching of this water-soluble material does not improve germination of A. confertifolia (Zavon and Kay[2]) The thickness and dense, woody construction of the pericarp may inhibit germination, primarily by preventing adequate water and oxygen from reaching the embryo (Sabo and others 1979; Fernandez and Johnston 1980).

With these mechanisms in mind, work began to evaluate the roles of mechanical, osmotic, and permeability inhibitors of the pericarp.

MATERIALS AND METHODS

Seeds of A. confertifolia used in this study were furnished by Dr. James A. Young, range scientist for the Agricultural Research Service in Reno, Nev. The seeds were collected in December 1977, near Lone Pine Creek, Calif. A. hymenelytra fruits were collected on the west side of Panamint Valley in late spring 1980. A. spinifera fruits were collected on the west shore of Lake El Mirage in August 1980. All fruits were maintained under warehouse condition in cloth or paper bags until the study began, January 1982.

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[1]Stutz, H.C., Prof. of Botany, Brigham Young University, in a letter addressed to Jeff Norton, Univ. of Calif., Davis, Feb. 6, 1980.

[2]Zavon, J.; Kay, B.L., graduate student and wildlands seeding specialist of Dept. of Agronomy and Range Science, Univ. of Calif., Davis, Unpublished data; 1981.

Four replicates of 25 seeds were used in each germination treatment, and germinated in petri dishes at 60°F (15°C). Since natural germination occurs under diurnally varying temperatures, germinating at a constant temperature may have biased the results. Where seeds were excised, as many fruits as it took to yield 25 seeds were used. The number of fruits dissected per treatment was used as the denominator for the germination percentage calculation. Seeds were considered germinated when radicles emerged 0.08 in. (2mm) beyond the testa. Statistical analysis was limited to t-tests done after arcsine transformation was performed on the percentage data (Steel and Torrie 1980).

Comparison of pericarp weight, seed weight, and germination for Atriplex hymenelytra, A. confertifolia, and A. spinifera was performed by excising seed from pericarps in four replicates of 25 fruits for each species and dividing the weights by the number of pericarps or seed within each replicate to give individual seed or pericarp weights. Germination during this comparison was done on four replicates of 25 intact fruits for each species at a constant 60°F (15°C).

A 0.2 percent solution of tetrazolium chloride in distilled water was used to determine viability (Springfield 1970). Four replicates of 25 utricles were used. Utricles were soaked overnight. Seeds were then excised, dissected, and placed in the tetrazolium solution for 24 hours at 41°F (5°C). Radicles that stained red were considered viable. Seed fill percentage was calculated during excision of the seeds for staining. Seed fill is defined as the number of fruits containing well-developed seeds divided by the total number of fruits examined, and expressed as a percentage.

Imbibition rates for A. confertifolia, A. hymenelytra, and A. spinifera were measured by soaking four replicates of 100 utricles of each species, and weighing at 12-hour intervals, after blotting fruits on dry cloth towels. Testing for the presence of a nonwettable layer was done by breaking 50 fruits of A. confertifolia, and placing 0.016 square inch pieces of blotter paper within the pericarp remnants. The pericarp remnants containing the blotter pieces were then placed on moistened blotters in a petri dish, and left overnight. The next day, the colors of the blotter pieces were compared with blotter pieces placed on cellophane, a substance essentially impermeable to water. The cellophane, with dry blotter pieces on top, was in contact with the same moistened substrate as the pericarp remnants. Darkened blotter pieces were considered to have been wetted via conduction of water from the moistened substrate to the blotter pieces.

Water absorption by intact and excised seeds was measured by soaking four replicates of 25 intact utricles, and four replicates of 25 excised seeds before weighing. Both groups soaked for 72 hours. Seeds from intact fruits were then excised, blotted, and weighed. Values were expressed as weight per 100 seeds, although fewer than 100 seeds per replicate were weighed.

Analysis of pericarp leachate was done after grinding four replicates of 100 pericarps followed by extraction in 0.35 oz. (10 ml) of double distilled water, and 2 minutes of agitation. Osmolality was determined with a vapor pressure osmometer. Chloride analysis was done titrametrically, and sodium was analyzed by atomic absorption spectrophotometry. Osmolality of the prepared solutions was converted to osmolality of hydrated pericarps by dividing the weight of osmotica in the solutions by the amount of water absorbed by the pericarps during hydration.

4.2 oz. (120 ml) of 0.197, 0.288, and 0.345 molal leachate was prepared to test the response of seeds to the leachate and, in combination with exposure, to a saturated environment. Nine hundred and forty fruits were used to prepare the 0.197 molal solution, 1,200 fruits for the 0.288 molal solution, and 1,560 fruits for the 0.345 molal solution. The osmolality of these solutions was checked using a vapor pressure osmometer. The saturated environment was prepared by taking strips of cotton, saturating them in the various leachate concentrations, and placing 25 seeds between two strips of saturated cotton for each concentration. This procedure was used in a later experiment using only distilled water to saturate the cotton. Blotters were wetted with leachate to isolate the effect of leachate.

Four replicates of 100 seeds were soaked in petri dishes containing distilled water. Seed volume changes before and after soaking were measured using a graduated cylinder calibrated in 0.0036 oz. (0.1 ml) increments. Denser than water, the seeds sank to the bottom of the cylinder, and the change in the volume contained by the cylinder was recorded at 24-, 48-, and 72-hour intervals.

The pressure produced by swelling of an imbibed seed was measured by applying Van't Hoff's equation to four soaking solutions containing 0.05, 0.20, 0.25, and 0.35 molal sucrose (Nobel 1974). The path of imbibition was observed by weighing excised seeds after soaking for 24, 48, and 72 hours. Petri dishes were used to soak four replicates of 25 seeds per treatment. When seeds soaked for 72 hours showed only a 10 percent increase in fresh weight, the osmotic concentration of the solution was considered to be equal to the pressure the seed could produce during swelling.

Utricles placed on a scale were pressed with a stylus having an area of 0.0012 in^2 (0.077 cm^2), the approximate size of the seed radicle, to measure the strength of the pericarps. The scale reading at the moment of utricle penetration served as the numerator for the calculation of physical pressure required to break the pericarp. Twenty-five utricles, soaked for 24 hours, were pierced to test the effect of wetting on pericarp strength. Twenty-five dry utricles were pierced to measure pericarp strength when dry.

Bract removal was done using a paper cutter. Leaching was done by placing seeds in cheesecloth, then placing the cheesecloth packets in a mason

jar having a screen-mesh lid, through which water was run for 12 hours.

Replacement of seeds in broken pericarps was done to test the effect of pericarp-bound inhibitors on excised seeds. The change in contact area between the pericarp and seed following excision and replacement was of negligible importance to evaluating the response (Sedgeley 1963).

Sulfuric acid treatments used were 0.25-, 0.50-, 1.0-, and 2.0-hour exposures of utricles to 98 percent acid. The hammermill treatment involved placing 3.5 oz. (100g) of utricles in the machine for 5 minutes. The freezing treatment involved soaking four replicates of 25 utricles for 3 days, and then freezing them for 24 hours before incubating 7 days at 60°F (15°C).

RESULTS

Table 1 shows the quantity of sodium chloride and other osmotica bound in hydrated pericarps of *A. confertifolia*. Table 2 compares the pericarp and seed weights of *A. hymenelytra*, *A. Confertifolia*, and *A. spinifera* and differences in germination among the three species.

Table 1--Analysis and percent composition of sodium chloride in hydrated pericarps of *Atriplex confertifolia*.

Analysis	Osmolality	Percent composition
	mol/kg	Percent
Sodium	0.045	16.6
Chloride	.034	12.5
Osmolality	.271	100.0

Table 2--Comparison of pericarp weight, seed weight, and germination for *Atriplex hymenelytra*, *A. confertifolia*, and *A. spinifera*.

Species	Weight of pericarp	seed	Germination
	-----mg------		Percent
A. hymenelytra	1.22a*	0.906a	45.1a
A. confertifolia	2.76b	0.904a	0
A. spinifera	2.74b	1.078a	0

*Means followed by the same letter are not significantly different at P<5 percent.

Table 3 shows the viability and seed fill of utricles collected from five locations and at different times. The values are consistently low, making germination improvement impossible for the majority of seeds. The Lone Pine Creek accession, collected in December 1977, was chosen for study because of its significantly higher viability and seed fill.

Table 3--Seed viability and fill of *Atriplex confertifolia* utricles collected in the Mojave Desert.

Location	Date collected	Tetrazolium viability	Fill
		------Percent-------	
Wacoba Springs	5/79	6	9
West Owens Lake	6/79	13	19
Southeast Owens Lake	8/79	17	23
Keeler	11/79	5	7
Lone Pine Creek	12/77	29	38

The germination percentage of seeds excised from pericarps resembled the viability value, yet, when intact, seeds did not germinate (table 4).

Table 4--Germination percentages of *Atriplex confertifolia* with pericarps excised or intact.

Treatment	Germination percentage
Pericarps excised	21[a]*
Pericarps intact	0[b]
Viability test with tetrazolium	29[a]

*Means followed by the same letter are not significantly different at P<5 percent.

In comparing the rate of water uptake by the utricle, *A. confertifolia* absorbed water faster during the first 12 hours of soaking than did either *A. hymenelytra* or *A. spinifera* (fig. 1). By demonstrating greater pericarp porosity than *A. hymenelytra*, a species that does not exhibit pericarp inhibition of germination (table 2), *A. confertifolia* germination is not likely inhibited by pericarp impermeability. Existence of a nonwettable layer between the seed and the pericarp is unlikely. Blotter paper placed inside broken pericarps absorbed water from a moistened substrate via the absorbent pericarp.

Table 5--Fresh weight of intact seed compared with excised seed soaked 72 hours.

Treatment	Fresh Mean	Weight Std. dev.
	-------g/100 seed-------	
Within pericarp	0.0983	0.0091
Excised	.1335	.035

Weighing hydrated seeds offered a method to test whether the amount of water absorbed by seeds that remained in their pericarps was significantly less than seeds soaked after being excised. Excised seed absorbed more water than seeds that remained within pericarps (table 5).

The significance level of this difference was P<8 percent using a one-tailed t-test at 6 degrees of freedom. The water not absorbed by the intact seeds may have been prevented from entering the seed by some mechanism other than impermeability.

Figure 2 shows germination response to the leachate extracted from a number of pericarps. Analysis of the leachate revealed that 30 percent of the osmotica was sodium chloride. The values given on the abscissa of this graph approximate the low, mean, and high values for the range of solute concentrations inherent to hydrated pericarps. The excised seeds germinated well in the presence of distilled water, but the highest solute concentration significantly decreased germination.

The results of exposing seeds to pericarp leachate was even more dramatic when simulating a low oxygen environment around the germinating seed. When seeds were placed between cotton saturated with the varying leachate concentrations, a significant drop in germination occurred at the lowest leachate concentration. However, this was, undoubtedly, not as much a response to the leachate, as a response to limited oxygen assumed to be characteristic of the saturated cotton environment. Saturation of the cotton with a leachate concentration of 0.345 molal yielded no germination from the exposed seeds. The significance of lowered germination in a solution-saturated environment is that it reflects the conditions that may be present when seeds held within hydrated pericarps are faced with low oxygen availability.

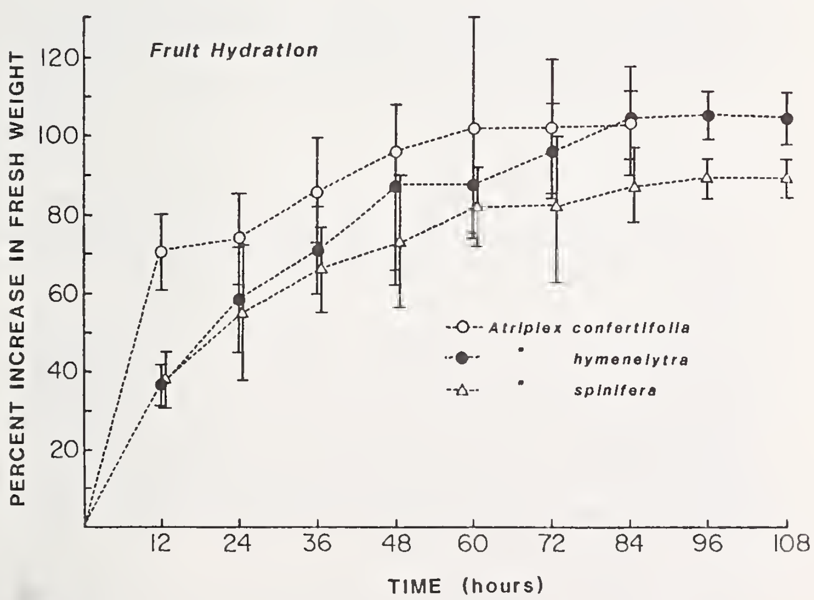

Figure 1--Fruit hydration of A. confertifolia, A. hymenelytra, and A. spinifera weighed at 12-hour intervals for a period of 108 hours.

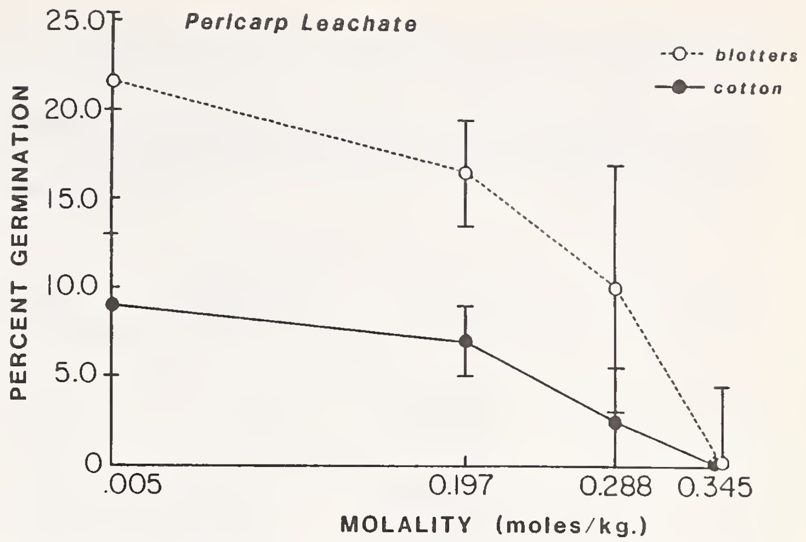

Figure 2--Germination in pericarp leachate of excised A. confertifolia seeds.

Observed early was the extreme tightness with which a seed is held by a pericarp; so much so that seed swelling would likely be inhibited when adequate water is provided for germination. In figure 3, data on seed volume change are plotted as a function of soaking. The change noted after 72 hours of soaking excised seeds was an average of 34.5 percent.

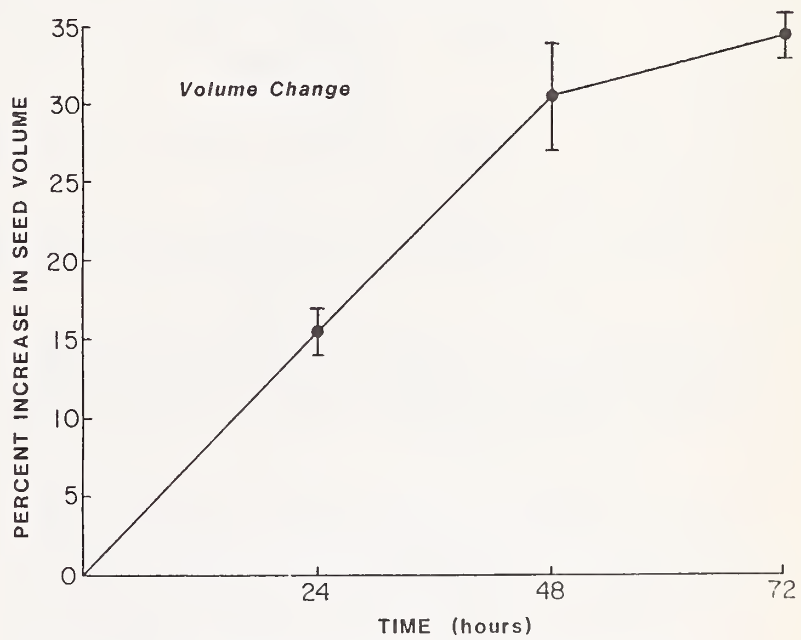

Figure 3--Volume change due to swelling of excised seeds following 3 periods of soaking in distilled water.

In order to facilitate that volume change, which preceeds germination, it is necessary for the seed to break the pericarp by the strength of its potential for water absorption. Expanding seeds continued to swell in solutions as low as -8.52 bars (figure 4). Thus, in pure water, it was assumed the pressure that could be exerted on the pericarp walls was about 8.5 bars (125 psi). In table 6, 8.5 bars, compared with the strength necessary to break pericarps,

reveals the extent to which seed swelling may be inhibited by the presence of the pericarp.

Table 6--Pressure required to break dry and moist pericarps compared with pressure developed by swelling seed.

Pericarp or seed	Pressure		
	Mean	Std. dev.	CV%
	--------------Bars------------		
Dry pericarp	302.3	224.5	74
Wet pericarp	115.9	80.5	69
Seed	8.5	--	--

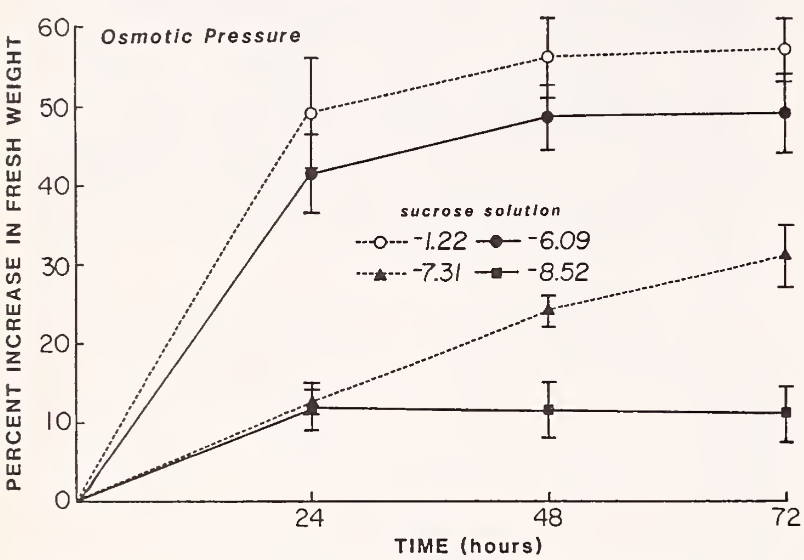

Figure 4--Percent change in fresh weight of excised seeds as a function of bathing in various concentrations of sucrose solutions.

Another plausible mechanism of germination inhibition was the resistance an emerging radicle would meet upon contacting the pericarp wall on its way out. When the bracts were clipped in order to allow radicles free access to the exterior of the pericarp, though, no germination ensued (table 7). The seed swelling and osmotic inhibitors were assumed to be intact. When the pericarps were broken, and the excised seeds were placed back in contact with them, germination occurred. Thus, assuming the broken pericarps mediated water transport to the seed, the salts found in the pericarps did not severely inhibit germination (table 7).

Table 7--Germination of leached fruits, fruits clipped just above the position of the radicle, and seeds excised and replaced inside the dissected pericarp from which they came.

Treatment	Germination
	Percent
Pericarp leached	0
Pericarp clipped	0
Replacement	12.6

Oxygen availability is severely limited when seeds are exposed to a saturated environment, such as that between layers of water-saturated cotton. When this is done to simulate the oxygen status of a seed within a hydrated pericarp, germination is depressed (table 8). However, some germination results.

Table 8--Germination of seeds incubated as follows: Group 1 - excised, placed on moistened blotters; Group 2 - excised, placed between layers of water-saturated cotton; Group 3 - intact utricles placed on moistened blotters.

Treatment	Germination			
	1st count, 6 days		Final count 14 days	
	Mean	Std.dev.	Mean	Std.dev.
Group 1	16.4(a)*	2.1	24.1(a)	3.2
Group 2	5.7(b)	0.8	8.6(b)	3.3
Group 3	0.0(c)	0.0	0.0(c)	0.0

*Means followed by same letter are not significantly different at P<5 percent.

DISCUSSION

The purpose of this research was to explain why germination was completely inhibited if the pericarp was left intact during incubation. Germination after pericarp removal demonstrates consistently that dormancy is maintained by the presence of the pericarp (Sabo and others 1979). The mechanisms investigated in this study point to a number of ways the pericarp might inhibit germination, however, only one mechanism was shown to have the potential for inhibiting germination completely.

After several attempts to enhance germination by leaching and nicking the pericarp in order to remove soluble germination inhibitors, and allow entrance of water and oxygen, still no germination resulted. These results make it clear that no amount of manipulation of the pericarp can

enhance germination short of its removal or weakening.

This experimentation into inhibition of seed swelling is by no means complete. Lack of data for seed volume change after soaking within the pericarp is unfortunate. Using the graduated cylinder to measure volume changes was not amenable to this experiment, because the drying of seeds taken from hydrated fruits results in reduction in density; they float on water (figure 3). Yet, no other mechanism tested here demonstrated the capacity to totally inhibit germination of viable seed.

Efforts to shatter or soften the pericarp by exposure to hammermill, sulfuric acid, or freezing of hydrated pericarps have met with little or no success. The hammermill treatment used offered the greatest success. After liberating 78 seeds from a group of about 1,450 viable utricles, 2.8 percent (40) of the viable seeds actually germinated. Sulfuric acid burned the embryo, and freezing hydrated pericarps did not result in their cracking, which, ostensibly, would have relieved inhibition of seed swelling.

In going through the long process of finding utricles bearing viable seeds, it helps to soak utricles for 24-48 hours, then hold them up to strong light. In most cases, the pericarp becomes translucent, and the seed within can be seen, if present. Seventy-six percent of the seeds found by this method were viable (table 1).

CONCLUSIONS

A pictorial representation of how dormancy regulators may interact in A. confertifolia is presented in figure 5. The various mechanisms all relate to either water or oxygen availability or to mechanical restrictions imposed by the pericarp. The pericarp did not inhibit water uptake via its hardness or density, because its composition was comparatively more hydrophilic than A. hymenelytra, a species which does not demonstrate pericarp inhibition of germination (figure 1). Water uptake by seed of A. confertifolia may be limited due to the reduced driving force for imbibition imposed by the solute concentration within hydrated pericarps. Not explored are the possible toxic effects of solutes or organic inhibitors that may exist.

Resistance to seed swelling can prevent germination (Crocker and Barton 1953). From evidence presented here, no other mechanism explains adequately the lack of germination. The tremendous difference between the pressure required to break pericarps and the pressure developed by swelling seeds shows that pericarps must be severely weakened or removed before germination can be achieved under artificial conditions. However, hammermilling utricles can destroy many more seeds than it liberates.

The attempt to crack and, thus, weaken pericarps by hydration followed by freezing resulted in no germination. The purpose of this procedure was to use the force of the expansion of water during freezing to crack the pericarps like a hammermill, but avoid damaging the seed. Perhaps, this procedure failed because the freezing rate of the ordinary freezer used in this experiment was inadequate.

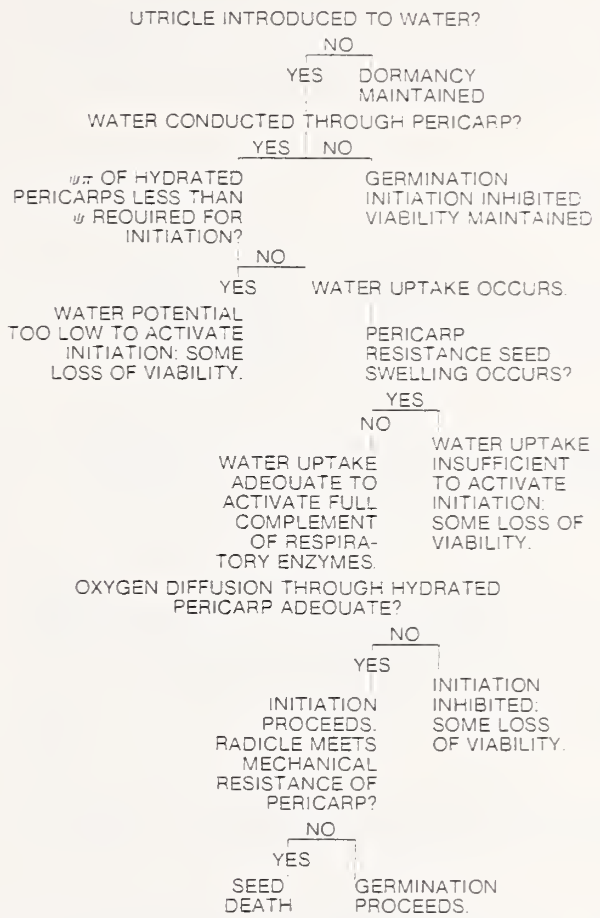

Figure 5--A. confertifolia germination model.

Efforts should be made in three directions to improve germination of A. confertifolia. (1) Varieties having softer pericarps should be selected and developed. The feasibility of this technique is somewhat questionable since most of the work in breeding saltbush is restricted to A. canescens (Carlson[3]). (2) A better hammermilling process should be developed, which minimizes seed destruction while abrading the pericarp sufficiently to break mechanical inhibition. (3) A method of freezing might be developed which actuates pericarp cracking enough to allow seed swelling.

The process of improving germination in A. confertifolia should not concentrate on conventional dormancy breaking treatments such as leaching or stratification (Zavon and Kay[4])

[3]Carlson, J.R., personal communication. Provo, UT; May 1983.

[4]Zavon, J.; Kay, B. L., graduate student and wildlands seeding specialist of Dept. of Agronomy and Range Science, Univ. of Calif., Davis. Unpublished data; 1981.

because these methods do not weaken the pericarp sufficiently. Occasionally, when utricles are left outdoors to overwinter dormancy is broken (Roundy[5]). Freezing under natural conditions may crack the pericarp, rather than enhancing the oxygen supply to the seed, which is the conventional mechanism of enhancement occurring during cool-moist stratification (Come and Tissaoui 1972). The objective of germination enhancement under artificial conditions should be to weaken or abrade the pericarp sufficiently to allow seed swelling, while avoiding damage to the seed.

PUBLICATIONS CITED

Beadle, N. C. W. Studies in halophytes. I. The germination of seed and establishment of seedlings of 5 species of Atriplex in Australia. Ecology. 33: 49-62: 1952.

Chatterton, N. J.; McKell, C. M. Atriplex polycarpa: I. Germination and growth as affected by sodium chloride in water cultures. Agron. J. 61(3): 448-450: 1969.

Come, D.; Tissaoui, T. Interrelated effect of inhibition, temperature, and oxygen on seed germination. In: Heydecker, W., ed., Seed ecology, 578 pp: Pennsylvania State University Press, University Port, PA: 1972: 15-168.

Crocker, W.; Barton, L. V. Physiology of seeds. Waltham, MA: Chronica Botanica Co.: 1953: 267 pp.

Fernandez, H. G.; Johnston, B. M. Effect of the testa in germination of Atriplex repanda. I. Water uptake in the seed. Phyton Rev. Int. Bot. Exp. 36(2): 97-102: 1978.

Fernandez, H. G; Johnston, B. M. Role of the pericarp of Atriplex repanda in germination. 2. Effects and characteristics of the aqueous extract of the fruit. Phyton Rev. Int. Bot. Exp. 38(1): 59-66: 1980.

Johnston, B. M.; Fernandez, H. G. Effect of the testa in germination of Atriplex repanda. 2. Determination of respiratory intensity. Phyton Rev. Int. Bot. Exp. 36(2): 103-110: 1978.

Koller, D. Germination regulating mechanisms in some desert seeds. IV. Atriplex dimorphostegia. Ecology. 38(1): 1-13: 1957.

Lailhacar-Kind, S.; Laude, H. M. Improvement of seed germination in Atriplex repanda. Phil. J. Range Management. 28(6): 491-494: 1975.

Leslie, T. A.; Stutz, H. C.; Pope, C. L. Evolutionary studies of Atriplex germination investigations. Proc. Utah Acad. Sci. Arts Lett. 51(1): 193: 1974.

Nobel, P. S. Biophysical plant physiology. San Francisco: Freeman and Co.: 488 pp: 1974.

Sabo, D. G.; Johnson, G. V.; Martin, W. C.; Aldon, E. F. Germination requirements of 19 species of arid land plants. Res. Pap. RM-210. Fort Collins, CO: U. S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 35 pp: 1979.

Sedgeley, R. H. The importance of liquid seed contact during the germination of Medicago tribuloides. Aust. J. Agric. Res. 14: 646-654: 1963.

Springfield, H. W. Germination and establishment of fourwing saltbush in the southwest. Res. Pap. RM-55. Fort Collins, Co: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 48 pp: 1970.

Steel, R. G. D.; Torrie, J. H. Principles and procedures of statistics. New York: McGraw-Hill: 633 pp: 1980.

West, N. E. Regenerative adaptations of native perennials to cold deserts of western North America. In: Abstracts of the papers presented at the XI International Botanical Congress and the International Wood Chemistry Symposium; XI International Botanical Congress; Seattle, Wash., 1969: 260 pp.

[5]Roundy, B. A., personal communication. Provo UT; May 1983

In: Tiedemann, Arthur R.; McArthur, E. Durant; Stutz, Howard C.; Stevens, Richard; Johnson, Kendall L., compilers. Proceedings--symposium on the biology of Atriplex and related chenopods; 1983 May 2-6; Provo, UT. General Technical Report INT-172. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 309 p.

Section 5. Seed Technology

ATRIPLEX CULTIVAR DEVELOPMENT

Jack R. Carlson

ABSTRACT: The flexibility of Atriplex, with its varying ploidy levels and ability to easily hybridize, makes it a valuable genus for reclamation, forage, and wildlife and livestock habitat improvement projects. The demand for Atriplex seed is substantial and increasing. Wild harvested seed can satisfy most of the demand, but is not widely adaptable. Several cultivars are being extensively tested for wide adaptability to fill this need. Cultivars also provide higher seed yields and seed quality than wild stands. Four Atriplex cultivars are currently available: 'Wytana,' 'Marana,' and 'Rincon' fourwing saltbush, and 'Casa' quailbush. Priority should be given to development of shadscale, gardner saltbush, and other fourwing saltbush cultivars.

INTRODUCTION

Fourwing saltbush (*Atriplex canescens* [Pursh] Nutt.) currently is the most popular Atriplex species on the commercial seed market. An estimated 20,000 to 30,000 pounds (9,000 to 15,000 kg) of fourwing saltbush seed is collected annually from wild stands and sold for reclamation, range, and wildlife habitat seedings. Demand is substantial (McArthur and others 1978). Stands can be established using wild harvested seed (Plummer and others 1968; Springfield 1970; Graves 1976) and will perform well provided local seed sources are used. However, nearby sources often are not available for seeding projects. Sources farther away will not have proven adaptation unless previous research, by chance, has matched source with the site to be seeded.

Another problem is administrative. Seeding contracts do not always specify local wild seed sources. They often allow poorly adapted seed to be used for the job. "Source identified" classification is used by some state seed certifying agencies and is advocated by the Western Forest and Range Seed Council as a means of formalizing source designations for wild seed and of promoting their proper use in seeding contracts. The "source identified" class requires information on seed purity and germination, or on the pure live seed (PLS) content of each seed lot.

The "source identified" class, however, does not solve the problem of adequate supplies. Widely adapted cultivars will, for several reasons.

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First, a cultivar's wide adaptation is verified by field testing before it is released to commercial seed producers. Because it is widely adapted, a cultivar can be seeded on many more sites than a local source. Therefore, demand for the cultivar is higher and seed companies can afford to keep adequate supplies on hand. In the case of Atriplex cultivars, commercial growers establish and maintain cultivated seed orchards or fields. These orchards or fields usually are planted on good soils and can be irrigated, weeded, and sprayed for insect control, if necessary. As a result, seed yields are higher and more consistent than wild stands, seed quality is increased, and seed supplies are much easier to maintain.

Cultivars are given names, usually signifying a unique characteristic or something about its origin. For instance 'Wytana' is a contraction of Wyoming (Wy) and Montana (tana), indicating the adaptation of this fourwing saltbush cultivar to these two states. Cultivar names tend to promote visibility and acceptance by the contractor, user, seed grower, seed company, and other involved parties.

In the long run, cultivars provide for the most effective use of Atriplex species in revegetation programs because they will best match supply, demand, and performance.

IMPORTANCE OF BROAD GENE BASE

Cultivated varieties undergo a selection and breeding process. Breeders may exert strong selective pressure on several traits. As yields, quality, machine harvestability, and other attributes are enhanced, the gene base of the crop is substantially narrowed. This is common among cereals, corn, and other food crops. Such crops, as experience has shown, are often more vulnerable than wild populations to devastating diseases and insects, if breeders do not provide diversity through an array of suitable cultivars or within the cultivars themselves.

On the other hand, range forage breeders and those who select plants for reclamation emphasize diversity. Here, flexibility, the ability to perform well and reproduce on diverse sites, is a trait that is selected for. Synthetic and composite cultivars can bring several widely separated superior, yet diverse, sources together in one population. Other superior single-source populations may be kept deliberately variable to maintain their flexibility. A broad gene base in range and reclamation cultivars provides this flexibility.

In reclamation plantings, the cultivar should establish, provide effective cover, and produce adequate amounts of seed for future generations. The performance of the cultivar, perhaps, is not as important as the ability of its progeny to effectively occupy a site. Therefore, the seed produced by the cultivar must contain a variety of genotypes that will help the population make the necessary adjustments. In *Atriplex*, as discussed later, this flexibility can be provided through hybridization, as well as within a broad-base cultivar.

Atriplex is a highly variable and very flexible genus through the interaction of natural variability, polyploidy, and interspecific hybridization (Stutz 1982a, b). The genus lends itself readily to cultivar development, particularly of broad-base reclamation varieties. However, its agronomic potential should not be overlooked. Range sites that are suitable for reseeding to improve forage production and quality are more homogeneous than mine spoils, highway slopes, and borrow pits. Soils on sites suitable for range reseeding, although marginal for cropland, usually are deep, well drained, and fertile. They are unsuitable for cropland because of problems with field logistics or marketing, rather than limitations of the soil. For forage seedings on these sites, perhaps greater selective pressure can be exerted on leafiness, production, crude protein, palatability, and other attributes. The gene base will narrow somewhat, but use of synthetic or composite breeding techniques should prevent cultivars from becoming too narrow.

The potential of a reclamation or forage cultivar is demonstrated through field testing over a wide area under various site conditions. For instance, 'Rincon' fourwing saltbush was released on the basis of its good performance at 29 sites in Arizona, Colorado, Idaho, Oregon, and Utah, for a total of 256 evaluation years. Sites had an average of 9 to 23 inches (23 to 58 cm) of annual precipitation, ranged from 3,000 to 7,600 feet (900 to 2300 m) in elevation, and existing plant communities ranged from sagebrush through pinyon-juniper to mountainbrush.

HYBRIDS AND POLYPLOIDS

Much of the flexibility in *Atriplex* can be attributed to polyploidy and interspecific hybridization (Stutz and Sanderson 1979; Stutz 1982a). These characteristics have been instrumental in an explosive evolutionary phase for perennial *Atriplex* species as they invade new habitats produced as a result of the recession of Lake Bonneville in the past 10,000 years (Stutz 1978). The major trends of this evolutionary phase should provide the framework by which cultivars of *Atriplex* are developed.

According to Stutz, during the most recent ice ages, lakes Bonneville and Lahontan separated two major populations of *Atriplex*: *A. canadensis*, an extinct mesophyte to the north, fourwing saltbush to the south. As the lakes receded, both species began to invade the salty bottomlands, came together, and hybridized. From the north, *A. canadensis* split into three species (fig. 1): *A. falcata* (M. E. Jones) Standl., *A. tridentata* Kuntze, and *A. gardneri* (Moq.) D. Dietr. Fourwing saltbush, migrating from the south, hybridized with all three. It strongly interacted with gardner saltbush forming the subspecies *A. c. aptera*, which now ranges from Wyoming northward to Montana and the Dakotas. This subspecies is highly variable among populations as it adjusts to different environments throughout its range. Hybrids between fourwing and *A. tridentata*, because of different ploidy levels, are less stable and usually backcross to either parent (Stutz and others 1979). Hence, some populations of *A. tridentata* are highly introgressed by fourwing, and vice versa. Similarly, *A. falcata* has influenced, and has been influenced by, fourwing to the west in Nevada, Idaho, and Oregon. Additionally, in central Nevada, tetraploid fourwing has hybridized with diploid *A. falcata*, giving rise to the allohexaploid *A. canescens nevadensis* (Stutz and Sanderson 1979), which is prevalent enough to be considered as a primary germplasm source.

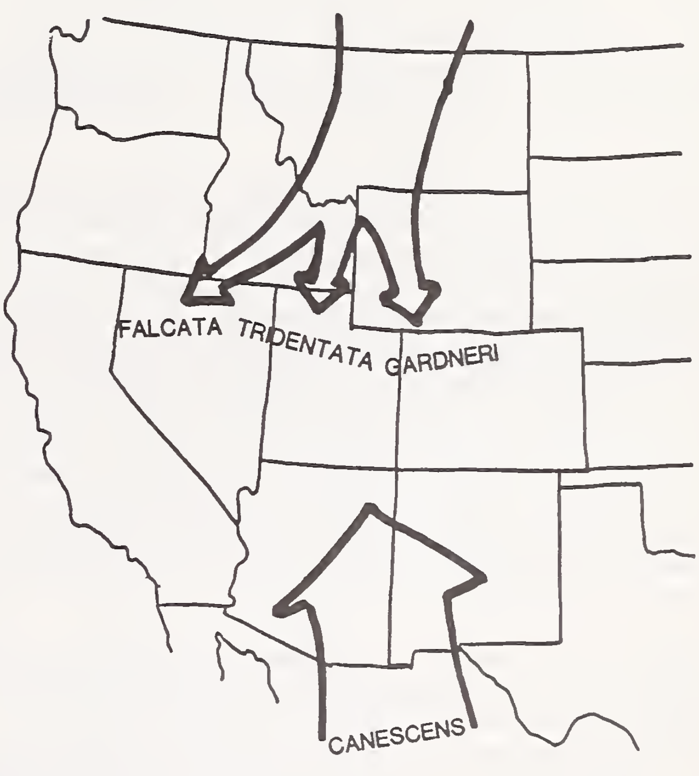

Figure 1.--Migration of *A. canadensis* and *A. canescens* populations into former Lake Lahontan and Bonneville area.

Fourwing saltbush has been significantly influenced by three other Atriplex species in the northern half of its range (Stutz 1982a; Blauer and others 1976). It has hybridized with desert saltbush, A. polycarpa (Torr.) S. Wats, in the Mojave and Arizona deserts, losing some of its cold hardiness but gaining drought tolerance. Fourwing also hybridizes with Castle Valley clover, A. corrugata S. Wats., and mat saltbush, A. cuneata A. Nels., but on a much more limited geographic scale than those described above.

In exploring the need for fourwing cultivars, it follows that populations introgressed by other major species would offer major possibilities. Major areas or centers of hybridization between species of Atriplex should be focal points for future cultivar development.

These focal points of hybridization, however, work less well for the second most widespread Atriplex species in the western United States, shadscale, A. confertifolia (Torr. and Frem.) S. Wats. In shadscale's case, polyploidy has been used to adapt to new environments (Stutz 1978). Shadscale primarily occurs in three ploidy levels, each found in a distinct habitat. The relic diploids occur in scattered populations above the Pleistocene lake levels. The autotetraploids are smaller and more compact and have invaded the lake floors in vast expanses. Octoploids, very uniform, short, squat plants, now occupy the lower bottoms. Decaploids also have been found, but only infrequently. However, the plants are vigorous, reversing the trend towards small, compact growth habit.

Ploidy levels also should help shape the direction of cultivar development in Atriplex. Diploid shadscale strains are not likely to perform well on tetraploid sites. For shadscale, the tetraploid form is the most widespread, so a cultivar should be developed for this form, at least. Perhaps another ought to be developed for octoploid sites, although octoploids may be difficult to handle agronomically. Shadscale has been tested very little in field plots, so not much is known of the effect of ploidy levels on site adaptation. However, the distinct natural lines of adaptation by ploidy level indicate the effect is probably strong.

Ploidy level also is an important consideration in other species of Atriplex, such as fourwing and gardner saltbushes, as well as Castle Valley clover. By considering the role of polyploidy with hybridization, we can outline potential sources of new cultivars that will cover most revegetation needs.

Four cultivars of Atriplex native to the western United States are now available. Three are fourwing saltbushes and one a quailbush, A. lentiformis (Torr.) S. Wats.

AVAILABLE ATRIPLEX CULTIVARS

'Wytana' fourwing saltbush was released in 1976 by the USDA Soil Conservation Service (SCS) and the Montana and Wyoming Agricultural Experiment Stations (AES). It originates from central Montana and is typical of the low-growing species in the region. It is a natural hybrid of A. canescens and A. gardneri named A. c. var. aptera (A. Nels) C. Hitchc. 'Wytana' performs very well on coal, uranium, bentonite, and hard rock spoils in Montana and Wyoming. Seed fields can be established and combine harvested using conventional equipment. The first significant commercial seed production fields were established in 1982.

'Marana' fourwing saltbush was released in 1979 for wildlife habitat plantings by SCS, California AES, and the California Department of Fish and Game. Recent tests show 'Marana' to be well adapted for reclamation in southern Arizona and possibly as far east as El Paso, Tex. It has performed well in direct seedings on Mojave Desert roadsides and reclamation seedings near Tucson, Ariz. 'Marana' originates from a population near El Cajon, Calif. (near San Diego). It is vigorous, robust, and tolerant of very hot desert environments. It does not tolerate temperatures below 10°F (-12°C), indicating possible introgression by desert saltbush, A. polycarpa (Torr.) S. Wats., a common occurrence among southern strains of fourwing (Stutz and Sanderson 1979). The ploidy level of 'Marana' is not yet established, but probably is tetraploid. Foundation plants will be available for seed orchards in 1984. About 10,000 plants are produced by commercial nurseries each year.

'Rincon' fourwing saltbush was released in 1982 by the Forest Service Shrub Sciences Laboratory (USFS), Utah Division of Wildlife Resources, SCS, and Colorado and Utah AES. It originates from north-central New Mexico at 8,000-foot (2450 m) elevation and is widely adapted in the Intermountain region (fig. 2). 'Rincon' was selected for superior seed production, annual biomass production, and evergreen condition. 'Rincon' has performed well on diverse sites as far north as Baker County, Oreg., and is recommended for reclamation and range seedings. 'Rincon' is tetraploid and representative of the most widespread form of the species. Crude protein ranges from 18 to 22 percent in leaves in August and November, respectively, and from 7 to 8 percent in stems. Commercial seed orchards were established in 1983.

'Casa' quailbush was released in 1979 for wildlife habitat plantings in California by the same agencies that released 'Marana'. Recent tests show 'Casa' also may be useful in reclamation plantings and range seedings as far east as Tucson, Ariz. Its range of adaptation roughly parallels that of 'Marana' (fig. 2). 'Casa' originates from

San Benito County, Calif. It lacks sufficient cold hardiness to be recommended throughout the range of the species; it cannot be established where temperature drops below 10°F (-12°C). Foundation plants for seed orchards will be available in 1984. About 15,000 plants are produced annually by nurseries.

Figure 2.--Ranges of three fourwing saltbush (A. canascens) cultivars.

DEVELOPMENT OF NEW CULTIVARS

Genotypic diversity, hybridization, and polyploidy provide Atriplex with a rich germplasm resource for the development of additional cultivars. The four available cultivars cannot be expected to meet the revegetation needs in the western United States for this important group of plants.

Major Atriplex Species

Fourwing saltbush -- Two additional tetraploid cultivars should be developed; one incorporating attributes from A. tridentata, the other from A. falcata (fig. 3). Five cultivars then would cover the range of the species within the western United States.

To the south, diploid fourwing becomes more prevalent, particularly on sandy soils. In central Nevada, the allohexaploid with A. falcata is extensive. Selections from populations of each should be evaluated against the standard cultivars to determine if further cultivars are needed. If demand is not likely to be sufficient to support another cultivar, perhaps a "source identified" could be applied.

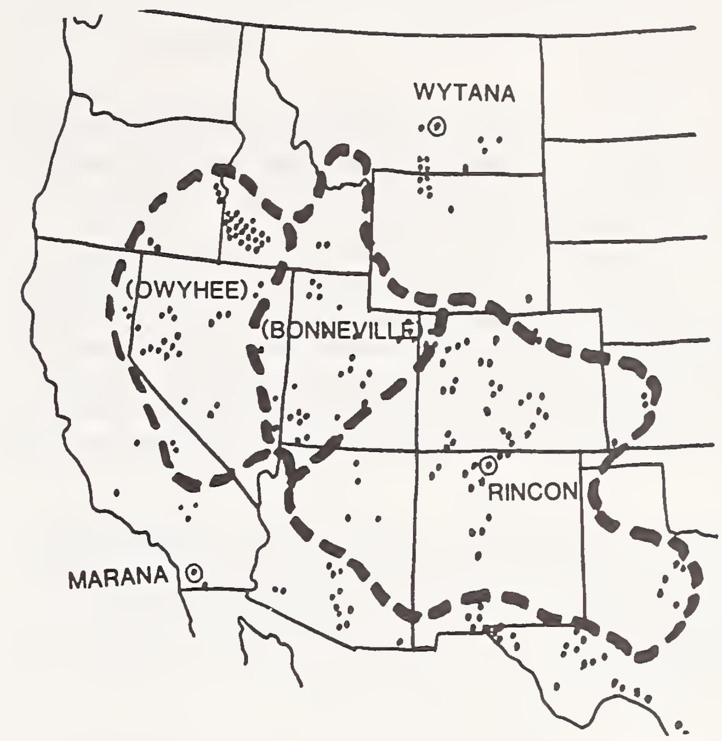

Figure 3.--Potential and available fourwing saltbush cultivars and their respective ranges in the western United States.

Shadscale -- At least a tetraploid cultivar should be developed. An octoploid cultivar would be desirable for dry, harsh, highly saline bottomland sites. However, most reclamation jobs probably involve more upland tetraploid or diploid sites. Major obstacles to shadscale domestication must be overcome, particularly poor seed dormancy and seedling establishment (Blauer and others 1976). However, some accessions recently have been successfully direct seeded in test plots on coal spoil near Rock Springs, Wyoming, and Farmington, New Mexico (SCS 1982).

Gardner saltbush -- This species covers more than 100 million acres (40 million ha), primarily in Wyoming and Montana. It is a dominant plant on many sites disturbed as a result of mining for coal, uranium, bentonite, and other raw materials. Diploids inhabit the uplands; tetraploids occupy bottomland sites. Two cultivars representing each ploidy level may be needed to meet the relatively high reclamation demand for this species. Evaluations are underway by the SCS Bridger Plant Materials Center (PMC) to develop these cultivars.

Desert saltbush -- This species is very drought tolerant and has been successfully seeded on highway slopes in the Mojave Desert (Clary 1983). One accession (PI399195) of desert saltbush, selected from a population near Blythe, Calif., is currently

the leading candidate for release by the Tucson PMC. It appears to be widely adapted through the range of the species. One cultivar should be sufficient for this species.

Other Species

Castle Valley clover and mat saltbush are important species in eastern Utah, western Colorado, and northwestern New Mexico. Because coal, uranium, and hard rock mining, as well as oil shale development, are common in this region, these two species are in moderately high demand for reclamation. Germplasm collection and evaluation have been very limited to date. Both hybridize with fourwing and shadscale as well as each other. Superior accessions should be systematically collected and evaluated for reclamation purposes.

Atriplex falcata and A. tridentata, which introgress into fourwing, are significant species in their own right (figure 4). Cultivars of each would be useful in seed mixtures with fourwing saltbush. Both are lower-growing with good erosion control characteristics.

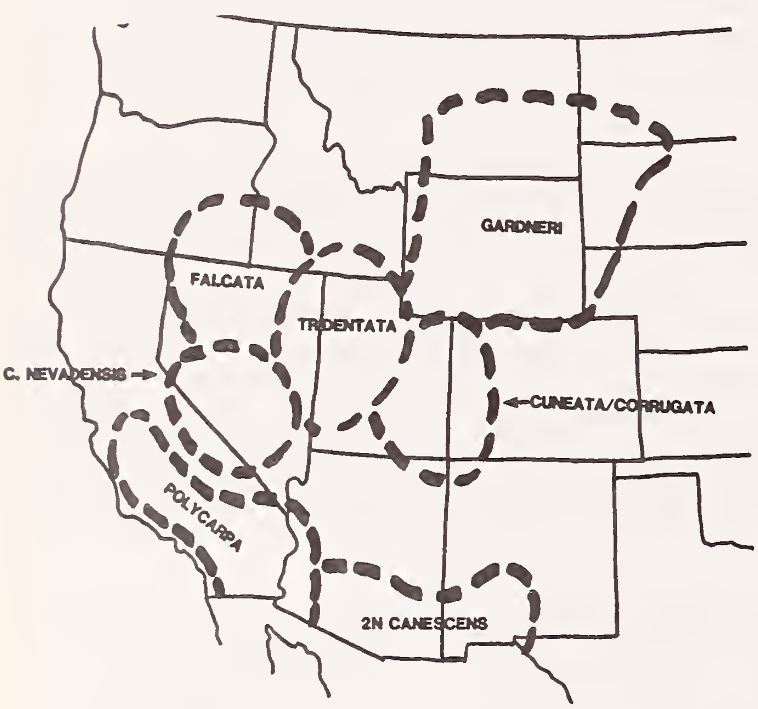

Figure 4.--General distribution of less widespread Atriplex species for which cultivars ought to be considered.

Forage Cultivars

In additon to its value as a reclamation genus, Atriplex has high agronomic value as a range forage, with many desirable traits. Most forage cultivars will likely be modifications of fourwing saltbush, the most widespread species and highest biomass producer. Drought tolerance is found in desert saltbush, seed harvestability in northern species of Atriplex. Castle Valley clover is more palatable and evergreen than other species. The ease of hybridization in Atriplex offers tremendous possibilities for its use as forage. It is hoped that a forage breeding program will soon be initiated.

Seed Mixtures

Seed mixtures used for reclamation usually include several species and attempt to reestablish, or at least mimic, the displaced native plant community. Many seed mixtures will continue to have Atriplex as a major component. This component should consist of at least the naturally occurring species near the site to be treated. Fourwing saltbush, because it is the most widespread, should form the backbone of most Atriplex seed mixture components.

If cultivars are developed as discussed above, reclamation specialists will be able to include in seed mixtures the Atriplex component best suited for the location and objective of the revegetation job (table 1). For example, for northwestern Utah the Atriplex components may consist of a tetraploid fourwing cultivar (Bonneville strain) introgressed with A. tridentata, an A. tridentata cultivar, and a tetraploid shadscale. Although all would have the potential to establish and provide ground cover, each would serve as a parent for future generations, probably hybrids, that would take over and be better adapted.

Table 1.--Atriplex seed mixture groupings.

Fourwing cultivar	Secondary components
Wytana (tetraploid)	A. confertifolia (tetraploid) A. gardneri (diploid and tetraploid)
Rincon (tetraploid)	A. confertifolia (tetraploid) A. cuneata A. corrugata A. tridentata (hexaploid)
Marana (probably tetraploid)	A. polycarpa (tetraploid) A. lentiformis 'Casa' A. canescens (diploid)
Bonneville strain (tetraploid)	A. confertifolia (tetraploid) A. tridentata (hexaploid) A. falcata (diploid)
Owyhee strain (tetraploid)	A. confertifolia (tetraploid) A. falcata (diploid) A. tridentata (hexaploid) A. c. nevadensis (hexaploid)

On the other hand, a forage seeding of Atriplex, although probably mixed with grasses, legumes, and other shrubs, could be with a single cultivar, perhaps with improved winter forage quality.

PRIORITIES

Given the enormous potential of the genus for reclamation and forage, priorities should be established for cultivar development. Table 2 provides one possible ranking and may represent the direction of the combined effort by several agencies on this group of plants at the present time. Of the high priorities, perhaps shadscale and Gardner saltbush warrant the most intensive effort, because they are critically needed for mine reclamation in the next two decades. 'Rincon' fourwing saltbush is widely adapted and could suffice until the other cultivars of fourwing are developed. However, since fourwing will provide the backbone for most Atriplex seed mixtures, it is advisable that the 'Owyhee' and 'Bonneville' strains be developed. In the long term, a forage variety of fourwing will have a large impact on a balanced forage program for Intermountain rangelands.

Desert saltbush is one of the easiest to directly seed and obtain adequate ground cover in the Sonoran Desert of the Southwest. Therefore, once released, it will be an essential component of our most drought-tolerant seed mixtures. Likewise, although more limited in range, mat saltbush and Castle Valley clover are important species for reclaiming mined lands in eastern Utah and western Colorado.

Other species are somewhat lower priority, but at least adequate germplasm should be assembled and evaluated. Some strains may be valuable sources of genes for infusing into the higher priority species, particularly for a forage cultivar.

Resources probably will not permit development of cultivars for all species and situations. Those who want to use the lower priority species may have to rely on "source identified" classification for seed quality and on local sources for adequate performance. A combination of cultivars and high-quality wild seed sources will be needed to meet the considerable demand for Atriplex.

Table 2.--Priority for cultivar release.

Cultivars	Release
Already released	
Fourwing saltbush (Wytana strain)	1976
Fourwing saltbush (Marana strain)	1979
Quailbush (Casa strain)	1979
Fourwing saltbush (Rincon strain)	1982
High priority	(Projected)
Fourwing saltbush (Owyhee strain)	late 80's
Fourwing saltbush (Bonneville strain)	mid 90's
Shadscale (tetraploid)	mid 90's
Gardner saltbush (diploid)	late 80's
Gardner saltbush (tetraploid)	late 80's
Forage fourwing saltbush	undetermined
Medium priority	
Desert saltbush (Mohave strain)	mid 80's
Castle Valley clover	undetermined
Mat saltbush	undetermined
Lower priority	
A. falcata	undetermined
A. tridentata	undetermined
Fourwing saltbush (diploid)	undetermined
Fourwing saltbush (hexaploid)	undetermined
Shadscale (octaploid)	undetermined

PUBLICATIONS CITED

Blauer, A. C.; Plummer, A. P.; McArthur, E. D.; Stevens, R.; Giunta, B. C. Characteristics and hybridization of important Intermountain shrubs. II. Chenopod family. Res. Pap. INT-177. Ogden, UT: U. S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1976. 42 p.

Clary, R. F. Planting techniques and materials for revegetation of California roadsides (In Press). Report to CALTRANS, Contract SA D13531. Davis, CA: Soil Conservation Service; 1983.

Graves, W. A. Revegetation of disturbed sites with native shrub species in the Western Mojave Desert. In: Kay, B. L. ed. Test of seeds of Mojave Desert Shrubs, Progress Report, BLM Contract No. 53500-CT4-2(N). Davis, CA: University of Calif.; 1976: 11-30.

McArthur, E. D.; Plummer, A. P.; Van Epps, G. A.; Freeman, D. C.; Jorgenson, K. R. Producing fourwing saltbush seed in seed orchards. IN: Proceedings of the first international rangeland congress; Denver, CO; Soc. Range Mgt.; 1978: 406-410.

Plummer, A. P.; Christensen, D. R.; Monsen, S. R. Restoring big game range in Utah. Publ. No. 68-3. Salt Lake City, UT: Utah Division of Fish and Game, 1968. 183 pp.

Springfield, H. W. Germination and establishment of fourwing saltbush in the Southwest. Res. Pap. RM-55. Denver, CO: U. S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1970. 48 pp.

Stutz, H. C. Explosive evolution of perennial Atriplex in western America. In: K. T. Harper and J. L. Reveal (eds.), Intermountain biogeography: A symposium. Great Basin Nat. Mem. 2: 161-168; 1978.

Stutz, H. C. Breeding superior plants for disturbed lands. In: Proceedings of western mined-land rehabilitation research workshop; 1982, June 10-11; Fort Collins, CO: U. S. Forest Service; 1982: 36-39.

Stutz, H. C. Broad gene pools required for disturbed lands. Proceedings of symposium for reclamation of mined lands in the Southwest; 1982 October 20-22, Albuquerque, NM: SCSA-NM Chptr.; 1982: 113-118.

Stutz, H. C.; Pope, C. L.; Sanderson, S. C. Evolutionary studies of Atriplex: adaptive products from the national hybrid, 6N A. tridentata X 4N A. canescens. Amer. J. of Botany. 66: 1181-1193; 1979.

Stutz, H. C.; Sanderson, S. C. The role of polyploidy in the evolution of Atriplex canenscens. In: Proceedings of the international arid lands conference on plant resources, 1979 July, Lubbock, TX: Texas Tech. Univ. Int. Ctr. for Arid and Semi-arid Land Studies; publisher; 1979: 1615-621.

U. S. Department of Agriculture, Soil Conservation Service. 1982 progress report: San Juan Coal Company field evaluation planting, waterflow, New Mexico. Los Lunas, N. Mex: Los Lunas Plant Materials Center; 1982. 10 pp.

In: Tiedemann, Arthur R.; McArthur, E. Durant; Stutz, Howard C.; Stevens, Richard; Johnson, Kendall L., compilers. Proceedings--symposium on the biology of Atriplex and related chenopods; 1983 May 2-6; Provo, UT. General Technical Report INT-172. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 309 p.

CONSIDERATIONS IN SELECTING CHENOPOD SPECIES FOR RANGE SEEDINGS

Mark Plummer

ABSTRACT: It is important before selecting chenopod shrub seed for vegetative rehabilitation, that careful consideration be given to the site conditions that will control its establishment and growth. Adaptability of strains, ecotypes, or biotypes to the site should be the primary consideration regardless of cost, since the purchase of seed on the basis of cost alone will most likely result in failure of the planting.

INTRODUCTION

The widespread use of native shrub seed in vegetative rehabilitation has generated a need for more conclusive information about shrub species and how they can be successfully planted (McArthur and others 1978). Suppliers of native shrub seed have an important role to fulfill in marketing seed appropriate for prescribed use.

In many cases, marginal results have been obtained from artificial seedings using native shrub species (Plummer and others 1968). This has caused many to question to what extent shrubs can be successfully established and what limiting factors are involved.[1] These questions most certainly must be addressed. However, before any final conclusions are made based on the success or failure of any one project, it is important to consider the seed planted.

Most of the chenopod shrubs commonly used to improve the quality and productivity of western ranges share common characteristics; that is, they have a wide range of distribution, but local and site characteristics control their occurrence.[2] The evolution and subsequent local adaptation of these shrubs over large areas has caused considerable variation in the germplasm of different populations and individuals. The tendency has been for many strains, ecotypes, and biotypes of the same species to be exhibited on western ranges (Stutz and others 1979). These genetic variants are obviously more adapted to certain localities and sites than others (Plummer and others 1955; Plummer and others 1968; Schopmeyer 1974; McArthur and others 1983).

Many theories have been offered to explain the variation exhibited in chenopod shrubs. However, the objective of this paper is to explain why this is important in the marketing of native shrub seed.

CURRENT MARKETING PRACTICES

Commercial dealers of native seed sell many thousands of pounds of chenopod seed each year for range improvement and reclamation purposes (McArthur and others 1978). Among the species most commonly sold are fourwing saltbush (*Atriplex canescens* [Pursh] Nutt.), shadscale (*Atriplex confertifolia* [Torr. & Frem.] Wats.), gardner saltbush (Atriplex gardneri [Moq.] D. Dietr.), and common winterfat (*Ceratoides lanata* [Pursh] J. T. Howell). With increased commercial availability of chenopod seeds, demand is increasing for other species also. These species include spiny hopsage (*Grayia spinosa* [Hook.] Moq in DC.), prostrate kochia (*Kochia prostrata* [L.] Schrad.), falcate saltbush (*Atriplex falcata* [Jones] Standl.), big saltbush (*Atriplex lentiformis* [Torr.] Wats.), and black greasewood (*Sarcobatus vermiculatus* [Hook.] Torr. in Emory).

The recognition and use of these shrubs has greatly increased the amount of seed available from seed companies (table 1). Unfortunately the information essential to successfully grow these shrubs has not been made equally available. In most cases, these seeds are collected from different ranges and widely varying sites; however, in purchase consideration is given only to seed available at the lowest cost.[3] There is increasing evidence that such marketing practices have resulted in the selection of seed not suited for the intended area (Secrist and Sands, these proceedings). It is obvious that more emphasis needs to be given to selecting seed according to origin and site adaptability. The education of the seed industry and consumers to this finding could well determine the success of native shrub seedings in the future.

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[1]Personal communications with several project supervisors; 1983.

[2]Plummer, A. P.; McArthur, E. D. Woody chenopods for reclamation of depleted and spoiled areas on arid ranges. Unpublished paper of Intermountain Forest and Range Experiment Station; 1975.

[3]Data on file at Plummer Plant and Seed Co., Ephraim, Utah.

Table 1.--Chenopod seed sales and collection data.[1]

Species	Developed cultivars	Est. lb. sold annually	Principal areas of collection	Seed crop frequency	Length of storage in years
Atriplex canescens	'Rincon' 'Marana' 'Wytana'	45,000	Western U. S.	yearly	10
Atriplex confertifolia		25,000	Intermountain and Southwest	yearly	10
Atriplex corrugata		2,000	Colorado River Basin, N. New Mexico	yearly	3
Atriplex lentiformis	'Casa'	500	Lower Great Basin	yearly	3
Atriplex gardneri		8,000	Montana, Wyoming, N. E. Utah	yearly	5
Atriplex cuneata		1,000	Colorado River Basin	yearly	8
Atriplex tridentata		1,000	Great Basin	yearly	4
Ceratoides lanata		20,000	Western U. S.	yearly	2
Kochia prostrata	'Immigrant'	100	Commercially grown	yearly	2
Sarcobatus vermiculatus		500	Western U. S.	yearly	5
Grayia spinosa		100	Western U. S.	yearly	2

[1]Table based on survey of major seed companies and supplies, 1982-83.

CONSIDERATIONS FOR SELECTING AND BUYING CHENOPOD SEED

The selection of shrub seed should involve the following considerations so that an ecotype or seed source which grows in conditions similar to those where it will be planted is selected.

Plant characteristics such as growth form, rooting depth, palatability, ease of establishment, and resistance to grazing should also be used in the selection of an adapted species or ecotype.

Growth Form

Many chenopods exhibit variations in growth form. Winterfat strains from the Northwest extending into Montana have been noted to have robust and tall growing forms, as well as shorter growing forms. Large stands of winterfat occur in the Great Basin area of Utah and Nevada. Generally winterfat in large intercompetitive stands tends to have a more short and contracted growth form.[4] As might be expected, border plants and those found in a less competitive association tend to be larger and produce more seed. Collections made by Plummer Plant and Seed Company from central Nevada in 1984 yielded 400 conditioned lb/acre of seed from the borders and edges of large nearly exclusive stands of winterfat, while the amount of seed produced within the stands was so limited it could not be economically harvested. Stevens and others (1977) consider an ecotype near Hatch, Utah, to be a large growth form and list several dwarf ecotypes, also. Southwest ecotypes are likely the largest. Particular notice has been given to a woody spinescent form (*Ceratoides lanata* var. *subspinosa*) occuring in the rocky hills of the southern desert shrub ranges of Utah, Arizona, California, and New Mexico.[2]

[4]Data on file at Great Basin Experiment Station, Ephraim, Utah.

Other chenopod species also exhibit this variation. Plummer Plant and Seed Company has made collections of low-growing small utricle forms of fourwing saltbush occurring on alkali flats in southern Nevada. In general, however, their collections comprise taller and large utricle forms.

Soil Type

Soil type also affects the adaptability of chenopod species. Fourwing saltbush, for example, has been observed to grow in sandy to gravelly loams, but some populations have also been found in clay loams.[2] Large areas of *Atriplex tridentata* occur on the heavy clay soils of the old Lake Bonneville lake bed (Stutz and others 1979). Common winterfat grows through a wide variation of sites and soils. On fine silty soils in desert areas, it often grows in nearly pure stands. The Hatch-type winterfat has been classified as a strain well adapted for juniper-pinyon soil associations (Stevens and others 1977). As already mentioned, the more woody spinescent form of common winterfat grows in the rocky hills of the Southwest.

All chenopods are generally more adapted to the arid alkaline ranges of North America. However, a wide range of tolerance has been demonstrated to alkalinity and high sodium salt concentrations in the soil. Shadscale and greasewood are chenopods with high tolerances to salty soils.[2]

Moisture Requirements

Chenopods differ significantly in their requirements for moisture. Greasewood is found both in well-drained and wetland soils. It frequently occurs in association with other chenopods adapted to saline-sodic soils and soils that are poorly drained, such as iodine bush (*Allenrolfea occidentalis* [Wats.] Kuntze), and sumpbush (*Suaeda* spp.). Other species such as spiny hopsage, fourwing saltbush, and Australian saltbush (*Atriplex semibaccata* R. Br.) are found in drier alkaline soils.[2]

Cold Tolerance

Several chenopods have such a great distribution range that they grow through wide climatic variation. Fourwing saltbush, black greasewood, and common winterfat grow from northern desert shrub ranges in Canada to southern desert shrub ranges in the southwestern United States and Mexico.[2]

This large range of distribution does not, however, infer that these species can be successfully planted throughout this range, but that an ecotype or genetic variant must be selected that will grow in the conditions desired.

With fourwing saltbush, it has been observed that southern ecotypes from warmer climates die out within a period of 3 to 8 years in more northern and colder climates.[4] In contrast, seed from more northerly latitudes has been successfully established in the warmer, more southerly latitudes. Closely associated with this observation and of equal importance is the elevation of the seed source. Sources from higher elevations tend to be more adaptable than those from lower and warmer elevations and in general reflect the greater adaptability of ecotypes from these areas (McArthur and others 1983). In addition, the recommendation that seed from nearby sources be used for vegetative rehabilitation has been substantiated (Van Epps 1975).

It is also important to consider that if proper selections are made, these species can extend their natural range occurrence. Fourwing saltbush and winterfat have been successfully grown in areas formerly dominated by sagebrush (Stevens and others 1977; McArthur and others 1983).

NECESSARY MARKETING CHANGES

The biological and ecological considerations listed above are some of the factors important in the selection of a seed source for a particular site. Unfortunately, most shrub species are often purchased only on the basis of cost and availability.

There are solutions to this problem that have already been developed to regulate the commercial sale of tree seed. A source identification system was initiated in the tree seed industry that identifies seed according to latitude, elevation, and precipitation. Maps have been devised which are zoned and categorized according to measurable factors that influence adaptability. In addition, collectors are issued permits which allow them to collect seed only from prescribed areas.

It is not infeasible to develop a similar system that will give buyers of native shrub species the same advantage in their revegetation efforts. Until such a system is completed, buyers have the responsibility to insist on background information for the seed they are buying. It is recommended that the following information be obtained from seed suppliers before any seed purchase is finalized:

1. Location of the seed source, including county, State, latitude, and National Forest, BLM District, or other land description.

2. Elevation of the seed source.

3. Soil type and description of the associated species.

4. Growth form of the parent plants.

5. Seed purity.

6. Seed germination, including date of the test and by whom the test was done.

7. Date of collection and method of seed storage.

This information must be requested by a buyer since it is not required. Many States do not have laws requiring the labeling of native shrub seed and it is not subject to laws regulating agricultural seed. As a practical matter, however, this information is essential to range managers, and without it they are not able to make good choices.

Contracts and bids generally require germination and purity standards. Nevertheless, there has been dissatisfaction expressed by buyers about failure of seed to meet agreed upon standards of purity and germination.[4]

ACKNOWLEDGMENTS

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PUBLICATIONS CITED

McArthur, E. D.; Plummer, A. P.; Van Epps, G. A.; Freeman, D. C.; Jorgensen, K. R. Producing fourwing saltbush seed in seed orchards. In: Hyder, D. N., ed. Proceedings, first international rangeland congress; 1978 August 14-18; Denver, CO. Denver, CO: Society for Range Management: 1978: 406-410.

McArthur, E. D.; Stevens, R.; Blauer, A. C. Growth performance comparisons among 18 accessions of fourwing saltbush (Atriplex canescens) at two sites in central Utah. J. Range Manage. 36: 78-81; 1983.

Plummer, A. P.; Hull A. C.; Stewart, G., Robertson, J. H. Seeding rangelands in Utah, Nevada, Southern Idaho, and Western Wyoming. Agric. Handb. 71. Washington, DC: U. S. Department of Agriculture; 1955. 73 p.

Plummer, A. P.; Christensen, D. R., Monsen, S. B. Restoring big game range in Utah. Publ. 68-3. Salt Lake City, UT: Utah Division of Fish and Game; 1968. 183 p.

Schopmeyer, C. S. Seeds of woody plants in the United States. Publ. 450. Washington, D.C.: U.S. Department of Agriculture; 1974. 883 p.

Stevens, R.; Guinta, B. C.; Jorgensen, K. R.; Plummer, A. P. Winterfat. Publ. 77-2. Salt Lake City, UT: Utah Division of Wildlife Resources; 1977. 41 p.

Stutz, H. C.; Pope, L. C.; Sanderson, S. C. Evolutionary studies of Atriplex adaptive products from the natural hybrid 6 N A. tridentata x 4 N A. canescens. Am. J. Bot. 66: 1181-1193; 1979.

Van Epps, G. A. Winter injury to fourwing saltbush. J. Range Manage. 28: 157-159; 1975.

In: Tiedemann, Arthur R.; McArthur, E. Durant; Stutz, Howard C.; Stevens, Richard; Johnson, Kendall L., compilers. Proceedings--symposium on the biology of Atriplex and related chenopods; 1983 May 2-6; Provo, UT. General Technical Report INT-172. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 309 p.

SEED PRODUCTION OF *ATRIPLEX CANESCENS* (PURSH)NUTT. IN SOUTHERN ARIZONA

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ABSTRACT: A vegetatively reproduced orchard of *Atriplex canescens* was established in August 1980 at the Tucson Plant Materials Center. The orchard design required 480 plants per acre (192 plants/ha) with 10 percent being male. Maximum distance of female to male plants was limited to 18 feet (5.5m). Initial harvest in December 1981 yielded 692 pounds of dewinged seed per acre (775kg/ha)--of that, 159 pounds (178kg) was pure live seed.

INTRODUCTION

Atriplex canescens (Pursh)Nutt. is used extensively in range improvement, and mine spoil and other disturbed site reclamation throughout the western United States. During 1980, 14 different companies offered this species for sale. Most of the seed sold was harvested from naturally occurring stands.

In a continuing effort to find and promote superior plants having conservation value, the Soil Conservation Service has released three cultivars--'Wytana,' 'Marana,' and 'Rincon'--from the Bridger, Mont., Lockeford, Calif., and Meeker, Colo. Plant Materials Centers (PMC's), respectively.

Techniques for large scale seed production are needed for wholesale seed producers, and for PMC's needing increased seed supplies for advanced adaptation and performance trials.

The Tucson PMC has evaluated *Atriplex canescens* extensively. Since 1977, 39 accessions have been comparatively evaluated at the Center. Accession T-3553 has consistently shown the best overall performance in both vigor and cover. A seed orchard of T-3553 was established at the Tucson PMC to produce a large quantity of seed for advanced testing and determine the effectiveness of the experimental orchard design.

T-3553 was collected from the Santa Rita Experimental Range located just south of Tucson, Ariz. in 1962. The site is at an elevation of 3,000 feet (914m) with soils described as Anthony fine sandy loam. Average annual precipitation is 11 inches (279mm). The site represents about 1 million acres (400,000 ha) of the upper limits of Major Land Resource Area (MLRA) 40 and lower limits of MLRA 41 in southern Arizona.

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METHODS

The seed orchard at the Tucson PMC was established from plants produced asexually at the PMC. All transplants were grown from stem cuttings segregated by sex of the parent plant. Transplants were used to ensure plants of a known sex within the orchard. Stem cuttings (approximately 1/8 inch [3mm] in diameter) were taken from succulent new growth and from hardwood in February 1980. Cuttings were placed in the greenhouse in aluminum trays containing 100 percent perlite. No rooting hormone was used. Cuttings were misted for 14 seconds every 15 minutes between 10 a.m. and 4 p.m. throughout the root development period. Within 8 weeks, 70 percent of the cuttings had rooted.

In April, the cuttings were transplanted into 4-inch (102mm) plastic pots, containing potting soil (one-third loam, one-third sand, and one-third peat moss and Osmocote--a slow-release fertilizer with 19-6-12 analysis [Osmocote has a release life of approximately 3-4 months]). In June, plants were transplanted to 1-gallon #10 cans and placed outdoors under 50 percent shade for further growth.

On August 27, 1980, plants were transplanted to a one-half acre (.2ha) field plot. Plants were transplanted in two 550-foot (168m) rows, spaced 15 feet (4.6m) apart with 5-foot (1.5m) spacing between plants within the rows. One male plant was planted for every ten female plants (fig. 1).

Figure 1.--Orchard design for 1 acre of *Atriplex canescens*. (Only two rows were actually planted at Tucson PMC.)

Plants were hand watered at planting (1/2 gallon [1.9ℓ] of water per plant) and flood irrigated (3 inches [8cm] of water) when planting was completed. Subsequent irrigations were also in 3-inch (8cm) increments. Irrigations through 1982 were as follows:

August 27, 1980	June 30, 1981
September 5, 1980	July 27, 1981
September 19, 1980	August 12, 1981
December 5, 1980	September 18, 1981
March 27, 1981	December 31, 1981
April 28, 1981	May 20, 1982
June 2, 1981	

Only one irrigation was required in 1982 due to above average rainfall (table 1). Two fertilizer applications were made in 1982 totaling 180 pounds of ammonium phosphate (16-20-0) per acre (202kg/ha). The seed orchard was not fertilized in 1983 because large plant size limited equipment operation.

Weed control is minimal due to shading and moisture competition by *A. canescens*. Since 1980, the only required weed control has been selective removal of tumbleweed (*Salsola kali*) and desert broom (*Baccharis sarothroides*).

RESULTS AND DISCUSSION

The orchard was harvested by hand stripping on December 22, 1981, and December 15, 1982. Lack of suitable mechanized equipment required hand stripping. A gasoline-powered, backpack-type vacuum harvester was tried unsuccessfully. There was insufficient suction to dislodge seed from plants. Metal tines were attached to the vacuum, but these too were unsuccessful due to intermittent clogging.

Hand stripping required 5 people working 60 hours to harvest the two 550-foot (168m) rows of T-3553. After harvest, the seed was spread on a protected concrete slab to thoroughly air dry before further seed conditioning. Once completely dried, the seed was milled to remove wings from the fruit. The seed was then processed through an air-screen separator. A total of 277 pounds (126kg) of clean, dewinged fruit was obtained from the two rows.

Based upon the actual two-row yield, a per acre yield of 692 pounds (775kg/ha) of clean, dewinged fruit was obtained from the 1981 harvest. Eight hundred and seventy-five pounds of winged seed per acre (980kg/ha) was harvested in 1982. Based upon past seed conditioning results, a weight reduction of 25 percent in the dewinging process is usual. Reducing the 1982 weight by 25 percent would result in a per-acre yield of 656 pounds of dewinged seed (735kg/ha).

Eighty-two percent of the utricles of the 1981 T-3553 harvest were found to contain seed. Yields of 289 pounds of seed per acre (234kg/ha) with an 85 percent fill have been reported elsewhere (McArthur 1978).

To determine percent fill, 400 fruits were randomly selected and excised. Of the 82 percent of filled fruits, not all appeared healthy. Twenty-five percent of the filled fruits were of low quality. Seed was classified as being of low quality if shriveled or damaged. Subtracting the 25 percent low-quality seed from the total fill of 82 percent results in a fill of 57 percent. The per acre yield of T-3553 then is 429 pounds of seed (480kg/ha), a substantial increase over the 289 pounds (324kg/ha) reported by McArthur.

Yields of two other accessions from the New Mexico and California PMC's have been 50 to 70 pounds per acre (56 to 78kg/ha). These orchards have a much higher percentage of males to females and no attempts were made to optimize the number of seed-bearing plants.

Germination of *A. canescens* T-3553 seed was determined 1 year following harvest. Germination tests

Table 1.--Climatic data at the Tucson Plant Materials Center, averaged for 1980-1982.

	1980					1981					1982				
	Temperature				PPT	Temperature				PPT	Temperature				PPT
Mon	Avg Max	Avg Min	Max	Min		Avg Max	Avg Min	Max	Min		Avg Max	Avg Min	Max	Min	
	- - - - °F - - - -				Inches	- - - - °F - - - -				Inches	- - - - °F - - - -				Inches
Jan						67	42	83	32	0.90	62	38	83	28	2.22
Feb						72	41	90	29	.93	68	41	88	30	.46
Mar						71	42	84	36	1.36	71	44	82	32	1.16
Apr						85	53	94	39	.58	82	49	93	39	.00
May						88	57	94	50	.59	88	56	98	47	.14
Jun						102	70	109	62	.06	98	61	107	55	.00
Jul						98	72	107	68	2.66	98	71	107	61	2.61
Aug	97	69	106	60	3.11	97	74	107	65	.51	97	72	105	66	5.21
Sep	95	63	104	55	1.21	95	66	103	56	.48	90	62	102	50	2.14
Oct	84	52	104	38	.45	84	53	94	36	.21	82	45	93	35	.00
Nov	75	41	94	30	.00	79	44	89	33	.75	66	41	80	28	2.08
Dec	73	53	83	30	.29	66	34	86	26	.00	58	32	75	22	2.03
Annual					5.06					9.03					18.05

Table 2.--Germination test results of *Atriplex canescens*.

Lot number	Harvest date	Test date	Percent germination	Remarks
T-3553 at Tucson PMC:				
6076	1978	3/79	26	Range harvest
		[1]6/83	24	
6102	1979	6/81	24	Range harvest
		6/83	14	
		6/83	16	
6125	1979	6/83	9	PMC increase
6164	1980	6/83	8	PMC increase
6224	1980	3/81	18	PMC increase
		6/83	12	
6283	1981	6/83	28	Seed orchard
6318	1982	6/83	11	Seed orchard
'Marana' at Lockeford PMC:				
Blend of	1976-79	7/80	52	
76-77-79		3/81	14	
		10/81	51	
		12/82	44	
T-4474 at Los Lunas PMC:				
SFP-77-JT	1977	3/78	47	Range harvest from Juan Tabo Canyon
		3/80	57	
SFP-78-JT	1978	1/79	29	Range harvest from Juan Tabo Canyon
		8/80	37	
SFP-79-F14	1979	2/80	33	PMC increase
SFP-80-JT	1980	12/80	32	Range harvest
SFP-80-F14	1980	2/81	[2]34	PMC increase
SFP-81-JT	1981	5/82	42	Range harvest
SFP-81-F14	1981	6/82	24	PMC increase

[1]All tests dated 6/83 were performed by Agricultural Labs, Inc.
[2]14 percent dormant.

run at the PMC resulted in 10 percent germination for the 1981 harvest. A tetrazolium chloride (TZ) test (Springfield 1970) was also run on seed of the 1981 harvest. This indicated 14 percent seed viability.

Germination tests performed by Agricultural Seed Laboratories, Inc., Phoenix, Ariz. in June of 1981 indicated germination of 28 percent for the 1981 harvest and 11 percent for the 1982 harvest (table 2). The germination of the 1982 harvest may increase after further ripening (Foiles 1974).

Germination of T-3553 appears lower than other fourwing accessions in the PMC program (table 2). The inherently lower germination of T-3553 may be caused by a high proportion of non-viable gametes. Low viability of filled seeds is common to tetraploid populations of *A. canescens* (Stutz and others 1975). T-3553 appears tetraploid by both appearance and collection site.[1] McArthur (1977) reported tetraploids are able to change sexes under stress with more than half of the population able to do so. In the population studied, a genotype frequency for male and female expression on the same plant was 55 percent with a phenotypic frequency of 10 percent in normal years. Changes of sex have not been noted in the established orchard of T-3553.

[1]Stutz, H. C. Tucson, AZ: Personal communication with author while at Brigham Young University Symposium, 1983.

T-3553 produces seed on first-year wood. Its ability to do this consistently was tested by pruning half of the orchard following initial harvest in 1981. Some plants were severely pruned (90 percent removed) while most were moderately pruned (50 percent removal). Seed production in 1982 was not affected by degree of pruning in 1981.

To assist potential growers of *A. canescens* in southern Arizona, a cost analysis of the PMC's 1981 seed harvest results was run using 1981 cost information for Pima County, Ariz. (Hathorn 1981) (table 3). Total per-acre production cost in 1981 was $942 ($2,328/ha) to produce 692 pounds (314/kg) of dewinged seed. This cost would return a per-acre profit of $787 to $1,133 ($1,944 to $2,798/ha), assuming a wholesale seed price of $2.50 to $3 per pound ($5.50 to $6.60/kg). The 1981 harvest was 159 pounds of pure live seed per acre (178kg/ha) as determined by germination tests in 1983. To obtain profits of $780 to $1,100 per acre ($1,927 to $2,717/ha), seed would have to be priced at $11 to $13 a pound ($24.22 to $28.63/kg) if the seed was sold on a pure live seed basis.

Hand harvesting accounted for 64 percent of the production cost. This cost could be substantially reduced by developing mechanized harvesting techniques and equipment. Irrigation requirements are substantially reduced after establishment.

Table 3.--Cost analysis of fourwing saltbush seed production at the Tucson Plant Materials Center, 1981.

Item	Cost/unit	Unit(s) used	Cost per acre
Irrigation	$ 53.57/acre ft	2 acre ft	$ 107.14
Fertilization:			
Ammonium phosphate (16-20-0)	210.00/ton	180 lb/acre/yr	19.80
Tractor (40 hp)	6.84/h		
Spreader	1.68/h		
Operator	4.00/h		
	12.52/h	1 h/yr	12.52
Cultivation/weed control:			
Tractor (40 hp)	6.84/h		
Rotary hoe	3.74/h		
Operator	4.00/h		
	14.58/h	2 h/yr	29.16
Harvesting:			
Hand stripping	4.00/h	150 manhours/5 rows (1 acre)	600.00
Seed conditioning	20.00/cwt	692 lb	138.40
Total production cost			$ 907.02
Orchard establishment:			
Plants (1-gal size)	0.48/each	approx. 480 plants	$ 230.00
Planting	4.00/h	32 manhours/acre	128.00
Total establishment cost			$ 358.00
Annual cost, assuming a minimum life span of 10 years (Maintenance costs of orchard were not calculated in analysis because of insufficient data at this time)			$ 35.80
Total yearly production cost			$ 942.82

PUBLICATIONS CITED

Foiles, Marvin W. *Atriplex* L., Saltbush. In: Seeds of woody plants in the United States. Agric. Handb. 450. Washington, DC: U.S. Department of Agriculture; 1974: 240-243.

Hathorn, Scott, Jr.; Armstrong, James F. 1981 Arizona field crop budgets, Pima County, Tucson AZ: University of Arizona; 1981: 7, 47-50.

McArthur, E. Durant. Environmentally induced changes of sex expression in *Atriplex canescens*. Heredity. 38(1): 97-103, 1977.

McArthur, E. D.; Plummer, A. P.; Van Epps, G. A.; Freeman, D. C.; Jorgensen, K. R. Producing fourwing saltbush seed in seed orchards. In: Proceedings of the first international rangeland congress; 1978 August 14-18; Denver, CO. Denver, CO: Society for Range Management, 1978: 406-410.

Springfield, H. W. Germination and establishment of fourwing saltbush in the Southwest. Res. Pap. RM-55. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1970. 48 p.

Stutz, H. C.; Melby, J. M.; Livingston, G. K. Evolutionary studies of *Atriplex*: A relic gigas diploid population of *Atriplex canescens*. Am. J. Bot. 62: 236-245; 1975.

In: Tiedemann, Arthur R.; McArthur, E. Durant; Stutz, Howard C.; Stevens, Richard; Johnson, Kendall L., compilers. Proceedings--symposium on the biology of Atriplex and related chenopods; 1983 May 2-6; Provo, UT. General Technical Report INT-172. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 309 p.

SEED PRODUCTION TECHNIQUES OF TWO CHENOPODS:

GARDNER SALTBUSH (ATRIPLEX GARDNERI [MOQ.] D. DIETR.) AND WINTERFAT (EUROTIA LANATA [PURSH] MOQ.)

Jack R. Carlson, John G. Scheetz, and Wendall R. Oaks

ABSTRACT: Gardner saltbush (Atriplex gardneri [Moq.] D. Dietr.) and winterfat (Eurotia lanata [Pursh] Moq.) were tested at Soil Conservation Service (SCS) Plant Materials Centers (PMC's) in Bridger, Montana, and Los Lunas, New Mexico, to determine their value as reclamation and forage species on cultivated lands. Management techniques, including seedbed maintenance, harvest methods, and seed cleaning used to achieve optimal seed production, are presented in this paper.

INTRODUCTION

Several chenopods are being grown in irrigated fields and combine-harvested for seed. This paper presents seed production techniques for gardner saltbush (Atriplex gardneri [Moq.] D. Dietr.) and winterfat (Eurotia lanata [Pursh] Moq.). In addition, 'Wytana' fourwing saltbush (A. canescens var. aptera [A. Nels.] C. Hitch.) and 'Corto' Australian saltbush (A. semibaccata R.Br.) have proven to be valuable reclamation and forage cultivars, able to be combine-harvested with conventional seedfield management and harvesting equipment. 'Immigrant' forage kochia (Kochia prostrata [L.] Schrad.), a new chenopod release for range seedings, is also increased with conventional methods.

'Wytana' fourwing saltbush has been cultivated and studied extensively at the Bridger Plant Materials Center in Montana, for several years. Harvest techniques for gardner saltbush are similar. 'Wytana' data are given for the purpose of this study to supplement the data for gardner saltbush. A. canescens var. aptera (A. Nels.) C. Hitch. is a natural cross between fourwing and gardner saltbush. The 'Wytana' strain exhibits strong gardner saltbush characteristics.

In general, the two saltbushes are grown as farm crops under irrigation, swathed when seeds mature each year (beginning the second year), and combine-harvested. The stands are rotary mowed each fall to a 3-inch (8-cm) stubble height to manipulate the growth form of the plants. The numerous decumbent laterals thus left produce seed-bearing shoots the following year. Harvested seed is processed using a hammermill and four-screen air cleaner.

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GARDNER SALTBUSH

The seed production steps outlined by Stroh and Thornberg (1969) for 'Wytana' can be followed with slight modifications.

Gardner saltbush (A. gardneri [Moq.] D. Dietr.) was collected from a wild stand approximately 15 miles (24 km) south of Plevna in Fallon County, southeast Montana. The population was a layering type growing in colonies of 10 foot (3 m) diameter plants. The site was a cut slope of shaley clay at an elevation of 3,000 feet (915 m). Average annual precipitation is 12 inches (30 cm). The ploidy level is not known. However, the accession (labeled T5294) was collected from an upland site, and most upland sites are occupied by diploids. T5294 was planted at the Bridger PMC in a small increase plot in April 1969. This plot was harvested by hand for 6 years, resulting in 44.2 total pounds (20.9 kg) of clean seed. Converted average annual production was 433 pounds per acre (485kg/ha) (table 1).

Table 1.--Seed harvests from two plots of gardner saltbush, Bridger, Mont., 1970-79.

Field	Year	Irrigation (in.)	Fertilizer	Date Harvested	Clean Seed (lbs)	Yield (lbs/acre)
0.017	1970	6	0	10/16	13.3	780
acres	1971	9	0	10/14	15.7	924
planted	1972	0	0	10/18	2.4	139
4/15/69	1973	6	0	10/16	5.1	302
hand	1974	8	0	10/9	4.7	279
harvest	1975	6	0	10/9	3.0	179
Average		5.8	0	10/14		433
Total					44.2	
0.55	1975	6	0	10/3	101.2	185
acres	1976	3	0	10/14	68.8	125
planted	1977	6	0	9/26	40.2	73
11/30/73	1978	6	0	10/17	100.1	182
combine	1979	6	0	9/20	78.1	142
harvest						
Average		5.4	0	10/4		141
Total					389.0	
			Total		433.2	152

A larger field of about one-half acre (about 1/5 hectare) was planted in November 1973. This field was combine-harvested five times from 1975 to 1979. A total of 389 pounds (177 kg) of clean seed was produced, for an average annual yield of 141 pounds per acre (159 kg/ha). The difference between hand-collected and combine-harvested yields reflects difficulties with swathing the low, prostrate plants and the tendency of seeds to shatter. Changes in management techniques and harvesting might improve yields for large-scale production.

Seed Field Establishment

Like most cultivated crops, gardner saltbush requires a firm, weed-free seedbed, particularly when no herbicide program is used for seedling establishment. Fields should be direct seeded in cultivated rows with a dormant fall planting. At Bridger, fields are planted between October 15 and February 15 in 36-inch (90-cm) rows. Spring plantings in April or May are also possible. Plant 20 pure live seeds (PLS) per foot (30 cm) of row. Normally this results in 40 to 50 utricles per foot of row. At Bridger, a grass drill with depth band-controlled, double-disk openers places seed no deeper than one-half inch in the soil.

During the first year, weed control is the most important consideration. Fields are cultivated two to three times, depending on need, with standard cultivator blades and furrow openers on a tool bar. Hand hoeing is necessary, at least once, to remove weeds within the row. Fields are furrow irrigated to keep soil moisture above 50 percent field capacity. By September, plants are about 12 to 18 inches (30-46 cm) tall and wide. After several killing frosts (no later than the third week of November) the field is mowed to a 3-inch (8-cm) stubble height with a 7-foot (2.1-m) rotary mower.

In the second year, young shoots emerge from the prostrate stubble and achieve full canopy by mid-to-late summer. The field is cultivated once or twice and hand hoed at least once. Irrigation is reduced to once before flowering, and once after, following the recommendation of Johnson (1975).

Seed Harvest

Seeds begin to mature during September at Bridger. Harvest is as early as September 20, and as late as October 18. The field is first cut and windrowed with a hay swather. This permits some immature seed to ripen in the windrow. The harvested crop is then picked up with a conventional grain combine. Table 2 provides the settings for two combines used at Bridger for 'Wytana' fourwing saltbush. Only one of the combines has been used to harvest gardner saltbush.

Table 2.--Settings for two combines used to harvest gardner and fourwing saltbushes at Bridger, Mont.

Combine	Gardner saltbush	'Wytana' fourwing saltbush
Allis-Chalmers-72		
Cylinder speed	1,450 rpm	900 rpm
Screen	1/4 inch	9/16 inch
Cylinder spacing	3/16 inch	5/8 inch
Air	1/2 open	3/4 open
International Harvester-615		
Cylinder speed	-	925 rpm
Cylinder clearance	-	5/8 inch
Wind	-	500-640 rpm
Top chaffer	-	1/3 open
Bottom chaffer	-	1/3 open
Concave	-	1/2 closed

Low prostrate growth and the tendency of its seed to shatter, even with minimal handling, make gardner saltbush difficult to harvest. A vacuum harvester salvaged 100 pounds per acre (113 kg/ha) of shattered seed of 'Wytana' at Bridger in 1978. Similar results could be expected with gardner saltbush, although it has not been tried.

Managing Established Fields

Harvested fields are rotary mowed before the third week of November to a 3-inch (8-cm) stubble to macerate and distribute the combine-screening residue. Simizine, although not labeled for use on gardner saltbush, has been applied at a rate of 2 pounds per acre (2.2 kg/ha) on an experimental basis in the fall or early spring. This has helped to control weeds with no noticeable damage to the stand or to seed production.

Stroh and Thornberg (1969) preferred direct combine to swath-and-combine harvesting to reduce the shattering loss from 50 to 20 percent. Since then, however, swath-and-combine harvesting has been practiced to avoid machine clogging, inefficient screening, and increased drying time in storage associated with direct combining of fresh stems.

Management of the third and following years' fields is the same as for the second year. In early spring, before green-up, to provide additional weed control, a field may be rotary-hoed on the diagonal to the cultivated rows. A springtooth harrow also has been used successfully, but more plants are lost than with the rotary hoe.

Although gardner saltbush has not been grown on a field scale for more than five harvests, fields probably could be maintained longer without appreciable yield losses. 'Wytana' has been maintained for eight harvests at Bridger. Five to eight years field life is comparable to grass seed fields.

Seed Cleaning

Gardner saltbush seed is easily cleaned with standard screening and fanning equipment to remove dirt, trash, and weed seed. Seed does not have to be hammermilled. Table 3 provides the settings for the cleaning equipment used at Bridger.

Table 3.--Settings for M2B clipper cleaner used to clean seed of gardner saltbush at Bridger, Mont.

Cycle	Speed	Top screen	Bottom screen	Air-top slide opening	Air-bottom slide opening
1	350 rpm	#15	blank	8 inches	closed
2	350 rpm	#12	No.1-13	8 inches	closed

T5294 gardner saltbush averages 77,000 seeds per pound (169,000 seeds per kg), cleaned. Purity and germination statistics average about 95 percent purity, 40 to 50 percent fill based on tetrazolium (TZ) test, and 10 to 20 percent germination.

WINTERFAT

Winterfat (Eurotia lanata [Pursh] Moq.), considered by many to be Ceratoides lanata (Pursh) J.T. Howell, has been grown for seed at the Los Lunas PMC in central New Mexico since 1974. T4549, the strain planted, originated from a wild stand collected in 1958 about 60 miles (96 km) north of the PMC near San Luis in Sandoval County.

In April 1974, a 0.19-acre (0.08-ha) field was direct seeded to winterfat for seed production. In November of the same year, 6 pounds (2.7 kg) of clean seed was direct combine harvested (table 4). The following spring the field was enlarged by direct seeding an additional 0.66 acre (0.26 ha). This 0.85-acre (0.34-ha) field was harvested each year between 1975 and 1981, producing a total 235 bulk pounds (107 kg) of clean seed. Average production for each of eight harvests was 35 pounds per acre (40 kg/ha).

Table 4.--Harvests from seed fields of winterfat at Los Lunas, N. Mex., 1974-81.

Year	Acreage	Date harvested	Bulk pounds	Yield pounds per acre	PLS factor	PLS per acre
1974	0.19	11-7	6.0	32	-	-
1975	0.85	10-30	38.5	45	0.43	19
1976	0.85	11-1	64.0	75	0.34	26
1977	0.85	10-31	43.0	51	0.51	26
1978	0.85	-	10.0	12	-	-
1979	0.85	11-16	3.5	4	0.63	2
1980	0.85	-	33.0	39	-	-
1981	0.85	-	37.0	44	-	-

Harvests during 1978 and 1979 were much lower than expected. Simazine, at 2 pounds per acre (2.2 kg/ha), was applied in late winter from 1976 to 1979. By 1979, the field was considerably weakened. Simazine treatment was discontinued, and the field responded with somewhat greater vigor and improved seed production. Removing the 1978 and 1979 yield figures results in an average annual production of 43 pounds per acre (49 kg/ha), a 26 percent increase.

Top yield was 75 pounds per acre (85 kg/ha) in 1976 with 34 percent PLS (pure live seed), or 26 pounds PLS per acre. At 175,000 seeds per pound (385,000 seeds per kg), these production figures are low compared to most grasses and to the saltbushes reported in this paper.

Los Lunas currently is evaluating 53 new accessions of winterfat for improved seed production. The 'Hatch' strain (T7844) of winterfat, selected by the USDA Forest Service Shrub Sciences Laboratory, was established in a small field at Los Lunas in 1983, and may have a higher seed production potential than T4549. In a small plot evaluation at Aberdeen, Idaho, T7844 produced more than twice as much seed as eight other strains which had been selected for overall performance from a uniform garden nursery of 40 accessions.[1] T7844 originates near Hatch, Utah, 125 miles (200 km) north of San Luis, New Mexico. Hatch is 355 miles (568 km) south of Aberdeen. It is interesting that T7844 produces so well at Aberdeen, whereas T4549 blooms 30 to 45 days later and fails to pro-

[1] SCS, 1981, unpublished.

duce mature seed. The Aberdeen data indicate a wide variation in seed production among accessions, and latitude could be a major factor. The effect of moving winterfat accessions south of their origin for seed production is not yet known.

Although much remains to be learned about seed production of winterfat, guidelines can be established that will help in choosing accessions that should provide yields at least comparable to those at Los Lunas. Only local sources of winterfat, within 150 miles (250 km) of the proposed seed field, should be used to establish fields. Once an accession has been chosen, the following cultivation and harvesting techniques should be used to ensure optimal production.

Seed Field Establishment

Like gardner saltbush, winterfat requires a firm, weed-free seedbed for adequate germination and establishment. At Los Lunas, 36-inch (90-cm) rows are direct seeded no deeper than one-eighth inch (3 mm), with a Planet Junior shoe drill or conventional vegetable planter. Seeds with utricles removed are planted at a rate of 1.5 pounds per acre (1.7 kg/ha), or 20 pure live seed per foot of row. Seeded fields are kept moist with sprinkler irrigation until germinated seedlings send a root deep enough to permit less frequent irrigation.

Once seedlings are established and rows are distinguishable, fields are cultivated and hoed as needed to take out common weeds such as mustard, annual kochia, and pigweed. Three cultivations and hoeings are usually required. Irrigation is cut back to once every three weeks, enough to maintain soil moisture at 50 percent field capacity and produce vigorous growth. By the end of the first growing season, plants are 2 to 3 feet (0.7 to 1 m) high and have produced a harvestable seed crop.

Seed Harvest

Seed usually matures by late October. Combine harvest at Los Lunas has ranged from October 30 to November 16. Fields are direct-combined with a small grain harvester when seeds begin to shatter. Combine settings are provided in table 5. All air is closed off and very little litter or residue is separated from the seed by the combine. A very small amount of seed is lost as only very large material exits the combine via the straw walkers. Combine stubble height is 6 to 8 inches (15 to 20 cm).

Table 5.--Combine settings used to harvest winterfat at Los Lunas, N. Mex.

	Allis-Chalmers Gleaner K	International Harvestor 205
Cylinder spacing	1/4 inch	various
Cylinder speed	800 rpm	various
Ground speed	0.8 mph	0.8 mph
Screens	removed	removed

Managing Established Fields

Irrigation water is withheld during the spring, as late as possible, to prevent cool-season weed infestations. Although Simazine has been very effective in controlling weeds, it stresses established winterfat plants, inviting common root and foliar diseases, and should not be used. Irrigation also should be as infrequent as possible but enough to maintain plant vigor. Winterfat is very drought tolerant and should produce good seed with limited water. No fertilizer is applied at any time.

Established fields are cultivated and hoed two or three times each year to remove warm-season weeds. Surflan is being applied on an experimental basis at Los Lunas, but it is too early to tell whether it will be beneficial.

Seed fields apparently can be maintained for at least 10 years if kept weed-free and properly managed. Seedling establishment appears to be a major difficulty. New seedings at Los Lunas in 1981 and 1983 have been difficult to establish because of weed competition and the strict planting and irrigation techniques required for shallow seedings.

Seed Cleaning

Harvested seed has usually been hammermilled to remove the fluffy utricles. However, Booth (1982) reports better establishment by seeding whole fruits because utricle hairs anchor the seed to the soil surface and hammermilling damages seeds, thereby reducing seedling vigor. Hammermilling may be a questionable procedure; however, if not hammermilled, fruits may be difficult to separate from stems, leaves, and other litter collected in the field. Hammermilled seed can be effectively separated using a four-screen air seed cleaner. Threshed seeds are also easier to feed through conventional seeding equipment.

Cleanings from the first three screens are rehammermilled and run through the seed cleaner again. A disk separator is used to separate seed from fuzz and other minute residues. Table 6 presents cleaning equipment settings. This process has resulted in as high as 79 percent purity and 80 percent germination, or 63 percent PLS. However, PLS has been as low as 34 percent, indicating processing can be tricky. Not hammermilling may result in PLS of 30 percent or lower. More testing is needed to determine how to clean nonhammermilled seed. The advantages of leaving utricles and fruits intact may outweigh lower PLS percentages and the more difficult seeding methods for trashy seeds.

Table 6.--Seed cleaning equipment settings for winterfat processing at Los Lunas, N. Mex.

Equipment	Setting	Amount
Hammermill	speed	800 rpm
	clearance	1/4 inch
Clipper Model 297D four-screen air cleaner	top screen	#10
	second screen	#9
	third screen	#8
	bottom screen	1/14th
	fan	200 rpm
	upper air	1/4 open
	lower air	1/3 open
	shaker speed	500

T4549 winterfat averages about 175,000 hammermilled seeds per pound (385,000 seeds/kg). Nonhammermilled seed lots vary depending on purity and should be computed individually.

Unless carefully stored, winterfat seed deteriorates rapidly after harvest. Kay and others (1977) found that seed lots with a dessicant added maintained germination for at least 3 years; untreated seed was not viable 6 months after harvest. Springfield (1974) successfully stored winterfat seeds in sealed containers under refrigeration for 8 years. Unless proper large-scale storage facilities are available, seed should be planted soon after harvest, preferably within 6 months.

PUBLICATIONS CITED

Booth, D. T. The ecological, physiological, and morphological effects of threshing winterfat fruits. In: Procedures of symposium on reclamation of mined lands in the Southwest, October 20-22; Albuquerque, NM. Albuquerque, NM: SCSA-New Mexico Chapter; 1982. pp. 133-137.

Johnson, W. J. Factors affecting utricle fill in fourwing saltbush (Atriplex canescens [Pursh] Nutt.). Bozeman, MT: Montana State University; 1975. 42 pp. M.S. thesis.

Kay, B. L.; Brown, C. R.; Graves, W. L. Winterfat. Davis, CA: University of California; Mojave Revegetation Notes No. 20; 1979. 8 pp.

Springfield, H. W. Winterfat seeds viable after eight years refrigerated storage. J. Range Manage: 27:78; 1974.

Stroh, J. R.; Thornberg, A. A. Culture and mechanical seed harvest of fourwing saltbush grown under irrigation. J. Range Manage: 22:60-62; 1969

In: Tiedemann, Arthur R.; McArthur, E. Durant; Stutz, Howard C.; Stevens, Richard; Johnson, Kendall L., compilers. Proceedings--symposium on the biology of Atriplex and related chenopods; 1983 May 2-6; Provo, UT. General Technical Report INT-172. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 309 p.

ESTABLISHMENT AND INITIAL RESULTS FROM A 'RINCON' FOURWING SALTBUSH (ATRIPLEX CANESCENS [PURSH] NUTT.) SEED ORCHARD

Gary L. Noller, Sam E. Stranathan, and E. Durant McArthur

ABSTRACT: A 'Rincon' fourwing saltbush seed production orchard was established at the Meeker, Colo., Plant Materials Center in 1980 to evaluate its performance and to examine the seed production characteristics. Two replications of cloned and seedling plants were established. Survival in 1982 averaged 94.7 percent. Cloned plants had slightly better survival than seedlings. Seed production was first noted in 1981. Seed hand-harvested in 1982 averaged 117.3 pounds per acre (131.5 kg/ha), considering clones and seedlings together. Each of the two replications of clones produced more seed than either of the two replications of seedlings.

INTRODUCTION

A 'Rincon' fourwing saltbush (Atriplex canescens [Pursh] Nutt.) orchard was established at the Upper Colorado Environmental Plant Center (UCEPC), Meeker, Colo. The orchard was established to evaluate the performance of 'Rincon' at Meeker and to examine its seed production characteristics. 'Rincon' is a cultivar of fourwing saltbush, recently released by the Shrub Sciences Laboratory, Utah Division of Wildlife Resources, UCEPC, Soil Conservation Service, and the Agriculture Experiment Stations of both Utah State and Colorado State Universities[1].

The initial seed collection of 'Rincon' was made in 1957 at Rincon Blanco, three miles northwest of Canjilon, Rio Arriba County, N. Mex. The elevation of the site is 7,800 feet (2,377 m) and it receives about 15 inches (38.1 cm) of annual precipitation. Basin big sagebrush (Artemisia tridentata [Nutt.] spp. tridentata), fourwing saltbush, and seeded wheatgrasses (Agropyron spp. Gaertn.) are the most common plants on the collection site.

[1]McArthur, E. D., Stranathan, S. E., Noller, G. L. 'Rincon' fourwing saltbush--proven for better forage and reclamation. Rangelands. In press.

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'Rincon' was selected for release because of its wide area of adaptation, sustained forage production, erect growth form, and tendency to be evergreen. The area of adaptation for 'Rincon' is situated between the areas of adaptation for the other two cultivars of fourwing saltbush--'Marana' and 'Wytana' (fig. 1).

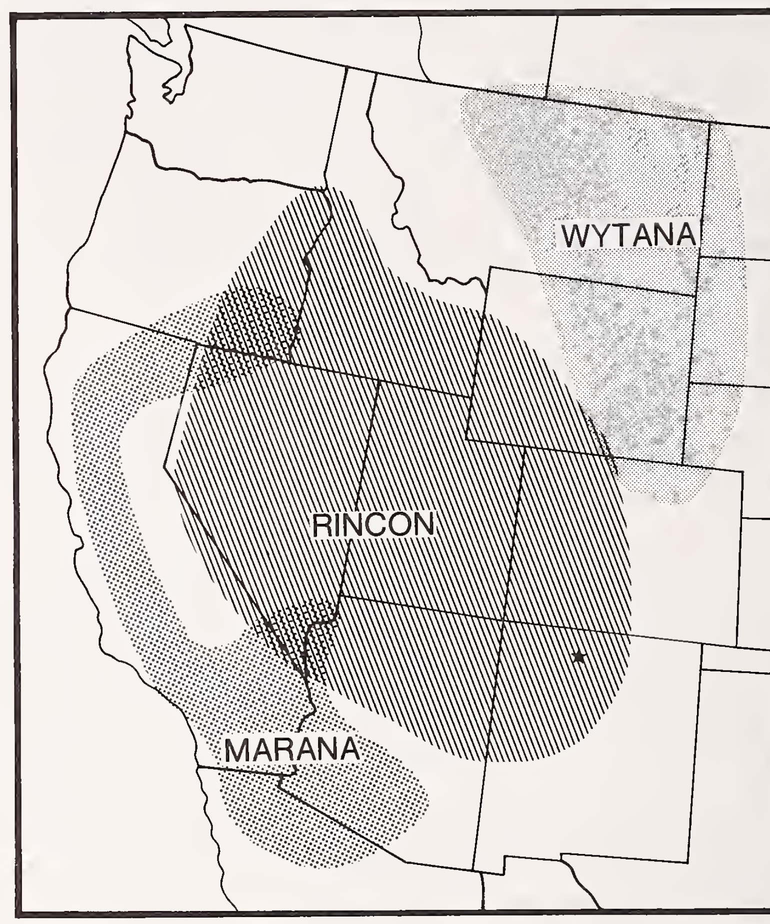

Figure 1.--Map showing adaptation of 'Rincon' fourwing saltbush. Original collection site: ★ Areas recommended for planting cultivars are shaded.

MATERIALS AND METHODS

The climatic conditions at the Meeker plant center are characterized by 16.19 inches (41.1 cm) of annual precipitation, 6,500 feet (1,981.2 m) elevation, and a 90-day frost-free growing season. Winter temperatures of -20° to -30° F (-28.9° to -34.4° C) are not unusual. Soils are silt-loam to silty-clay-loam. These conditions may be approaching the distribution limits for fourwing saltbush.

The field where 'Rincon' was planted was fallowed the year before planting and was relatively weed free at planting time. Nitrogen, phosphorus fertilizer (18-46-0) was applied at the rate of 100 lb per acre (112.1 kg/ha) and was disked in before planting.

The 'Rincon' orchard was planted May 27, 1980. The orchard design was a modification of the one presented by McArthur and others (1978) and was designed to accommodate field maintenance equipment, provide adequate pollen flow, and maximize seed production per acre (fig. 2).

Planting

Two replications of seedlings and clones were planted. The seedling plants were produced from seed; the cloned plants were propagated vegetatively from stem cuttings. Plants were spaced 9 feet (2.7 m) apart on the east-west axis and 12 feet (3.7 m) apart on the north-south axis. Cloned plants were planted in a ratio of one row of males to five rows of females. The rows were planted so the prevailing southwest winds during the pollination season could carry the pollen from the males to the females (fig. 2). Each row of females represented a particular numbered female, which was replicated three times in each planting of clones. These numbers refer to a planting in Utah from which the vegetative cuttings were taken to establish the Meeker orchard. The number for the cloned females represents a row, and the number of the plant within the row, from which the cuttings were taken. For example, 8-56 refers to plant 56 in row 8. Soil in the two replications of clones did appear to be different. The southwest replication of clones had an area with white surface soil. This was due to the uneven application of topsoil after the field was leveled for irrigation.

A total of 1,012 plants were planted in the orchard (506 seedlings and 506 clones). Holes were dug, water was added, and potted plants (provided by the Shrub Sciences Laboratory) were inserted and covered. Eight people using a truck and trailer completed the 3.1-acre (1.3-ha) planting in about 5 hours.

Field Maintenance

Watering.--The need for watering was influenced by the weather conditions. In 1980, only 14.63 inches (37.2 cm) of precipitation were recorded. The plants were watered when planted, watered again in mid-June and given an additional watering in mid-August. Approximately 1 gallon (3.8 l) of water was applied at the time of planting. Each irrigation application represented about 1-½ to 2 inches (3.8 - 5.1 cm). The year 1981 was considered wet with 19.02 inches (48.3 cm) of precipitation. No additional water was needed. The orchard was watered once in 1982 on about June 20. Rain occurred later in summer so no additional water was necessary. Precipitation for 1982 totaled only 14.84 inches (37.7 cm).

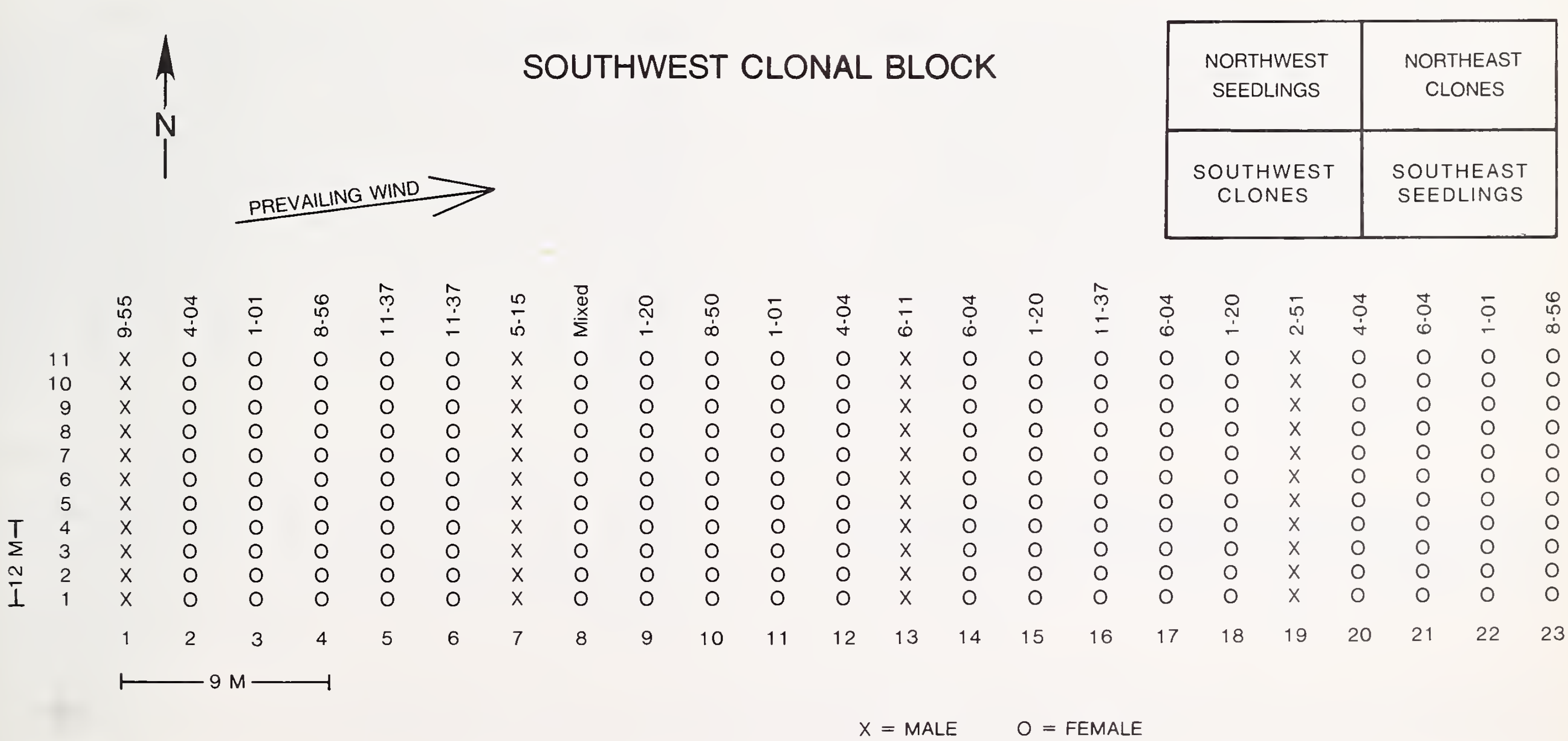

Figure 2.--'Rincon' orchard design showing the two replications of clones and seedlings. Each replication had plants spaced 9 feet (2.7 m) on east-west axis and 12 feet (3.7 m) on north-south axis. Cloned replications were planted in a ratio of one row of males to five rows of females. The numbered female and male rows are shown for the southwest replication.

The June watering in 1982 was important because it gave the plants an opportunity for early summer growth. This early growth was beneficial for taking cuttings for new seed orchard establishment.

Cultivation and weeding.--Cultivation and weeding were done in an attempt to prevent weeds from producing seed in the orchard. The 'Rincon' orchard has been maintained relatively weed free.

The orchard was hand-weeded approximately three times per year and mechanically cultivated with a tractor and a sweep-type cultivator approximately five times per year. The tractor was used to cultivate between the rows of 'Rincon' plants. However, at the present time, it is possible to cultivate with the tractor and 8-foot tool bar in only one direction, east and west.

Herbicides.--Shortly after planting, DCPA (Dacthal) was applied around the fourwing saltbush plants to reduce the germination of annual grasses and broadleaf species. DCPA was applied at a rate of 15 lb per acre (16.8 kg/ha) in a band treatment covering approximately one foot (30.5 cm) on each side of the plants.

Glyphosate (Roundup) was used as a spot treatment for control of Canada thistle (*Cirsium arvense* [L.] Scop.) and volunteer alfalfa (*Medicago sativa* [L.]).

Insect and disease control.--So far, there have been essentially no insect or disease problems in the 'Rincon' orchard. Potential insect or disease problems are monitored.

Data Collection

The 'Rincon' orchard has been evaluated at least once each year. The evaluations were made in mid-to late summer. Values were recorded for survival, vigor, height and crown growth, sex expression, and seed production. Height and crown growth were measured in centimeters and represent the tallest and widest growth of each plant. Numerical reproduction values represent an estimate of the abundance of male or female flowers (0 = none and 9 = abundant flowers). Vigor in general is an estimation of the quality and quantity of growth. Vigor of the plants was estimated and given a numerical value (1 = low and 9 = high vigor).

Data analysis.--Data were analyzed by analysis of variance with Student-Newman-Keuls comparison of means when appropriate and by chi-square analysis (Woolf 1968).

RESULTS

Survival

Survival of the entire 'Rincon' orchard to the fall of 1982 has been good. By the fall of 1980 (mid-to late September, approximately 4 months after planting) survival for the entire orchard averaged 98.7 percent (table 1). Seedling and clone survival were essentially the same, 99.0 percent and 98.4 percent, respectively. Mortality in the replications of clones in 1980 was attributed largely to the loss of one numbered female (8-56), which appeared to be somewhat desiccated at the time of planting. All of the males in both replications of clones were still alive.

In mid-July 1981, all dead plants were replaced. A total of ten seedlings were replaced, four in the northwest replication and six in the southeast replication. Twelve plants from the two replications of clones were replaced. Nine females from the southwest replication of clones were replaced (5 plants of 8-56, 2 plants of mixed, 1 plant of 1-01, and 1 plant of 6-04). Three females from the northeast replication of clones were replaced (2 plants of 6-04 and 1 plant of 4-04).

By early November 1981, no additional plants had died since the replanting in mid-July. Survival for the entire orchard averaged 97.9 percent (table 1). Seedling and clone survival were still essentially the same, 98.1 percent and 97.7 percent, respectively. Mortality in the clone replications was due entirely to the loss of females; all of the males were still alive.

By late August 1982, survival for the entire orchard averaged 94.7 percent (table 1). Cloned plants had slightly better survival than seedlings, 95.0 percent and 94.4 percent respectively. This was the first year that the clones expressed a better survival rate than seedlings. This also was the first year that the clones experienced any male mortality. However, male survival was still better than female survival, 96.6 percent and 94.7 percent, respectively. Mortality in the clone replications was due primarily to the loss of three females (8 plants of 1-20, 5 plants of 8-56, and 4 plants of 6-04) and one male (3 plants of 5-15).

The winter temperatures of 1981-82 were extremely cold. Two periods (one in early January and another in early to mid-February) had minimum temperatures colder than -20^{o} F (-28.9^{o} C). This was probably one of the important factors contributing to the 1982 mortality in the orchard.

Sex Expression - Seedlings 1982

In late August 1982, the sex expression for the two replications of seedlings was: 43.0 percent female, 30.2 percent male, 11.8 percent bisexual or monoecious, 9.1 percent flowerless, and 5.8 percent dead. When the nonflowering and dead plants were omitted, the sex expression did not differ significantly from that predicted by McArthur (1977) of 55 percent female, 35 percent male, and 10 percent monoecious.

Sex Expression - Clones

No shifts in sex expression in the clonal material have occurred during the study period.

Height and Crown Growth, Reproduction and Vigor - 1982

Height and crown growth, reproduction, and vigor were compared for clones and seedlings in late August 1982. The southwest replication of clones

Table 1.--'Rincon' survival by years for seedlings and clones.[1]

	Survival rate		
	Fall 1980	Fall 1981	Fall 1982
	- - - -	Percent	- - - -
Seedling:			
NW replication	99.6	98.4	94.2
SE replication	98.4	97.7	94.6
Average	99.0	98.1	94.4
Clone:			
SW replication			
Male	100.0	100.0	93.2
Female	97.1	95.9	93.1
Average	97.6	96.6	93.1
NE replication			
Male	100.0	100.0	100.0
Female	99.0	98.6	96.2
Average	99.2	98.8	96.9
Average for clones: (both replications)	98.4	97.7	95.0
Average for orchard: (Seedling and clone)	98.7	97.9	94.7

[1]The orchard was planted in May 1980. In mid-July 1981, all dead plants (10 seedlings and 12 clones) were replaced. The 1981 and 1982 data also reflect the replaced plants.

was significantly shorter than the southeast replication of seedlings (table 2). The northeast replication of clones had significantly larger crowns than the southwest replication of clones or either replication of seedlings (table 2). Reproduction was significantly more abundant in the northeast replication of clones and northwest replication of seedlings. Vigor was not significantly different in any replication of seedling or clone plants (table 2).

Height, crown, reproduction, and vigor were apparently not significantly different between male and female clones, although males tended to be taller and females broader (table 3). Female clones were taller, broader, and more vigorous on average than female seedling plants.

Seed Production

Estimated seed production in 1981.--Seed production was first noted in the fall of 1981, a year and five months after planting. The seed was not harvested, but an estimation was made for each plant as to whether its seed production was heavy, moderate, light, or very light. Considering the entire orchard in the fall of 1981, a total of 446 plants (44 percent) were producing seed. This represented 264 plants in the two replications of clones and 182 plants in the two seedling replications. Each replication of seedlings had 91 plants producing seed.

Considering the clones, the southwest replication had 125 females, or 29.9 percent, producing seed. The northeast replication had 139 females, or 33.3 percent, producing seed. The difference between the seed production for the two replications of clones could be caused by the soil differences discussed earlier.

The estimated 1981 seed production for the clones was noted for each numbered female. Female 11-37 had a large number of females producing seed in 1981 and was also a good seed producer in 1982. However, number 1-01 had no plants producing seed in 1981, but was a good seed producer in 1982. A large number of plants of female 1-20 were producing seed in 1981, but this female was not considered a good seed producer in 1982. This indicates that the seed production from the cloned plants in the orchard has not been consistent for each female. The consistency may improve as the orchard matures.

Seed production in 1982.--In 1982 the seed production from the 'Rincon' orchard was hand-harvested. Harvesting started in late October and was completed on November 18. Based on the 36 man-hours required for harvesting the northeast replication of the clones (the heaviest seed producer), approximately 144 man-hours were required for harvesting the entire 3.1 acre (1.3 ha) orchard.

Utricles from the northeast replication of the clones were examined for fill and averaged 51.5 percent. A fill of 50 percent for a wild stand of fourwing saltbush is regarded as good (Gerard 1978).

Utricle fill was examined in relation to the position on the plant where the seed was found (table 4A). The position on the plant did not have a significant influence on utricle fill.

Table 2.--A comparison of height, crown, reproduction, and vigor by analysis of variance (all blocks) for both replications of clones and seedlings.

	Height	Crown	Reproduction[1]	Vigor[1]
	-- centimeters --			
Northeast clone	109.3 ab[2]	213.8 a	6.1 a	7.7 a
Southwest clone	106.7 b	188.9 c	5.0 b	7.6 a
Southeast seedling	111.2 a	203.7 b	4.6 b	8.0 a
Northwest seedling	108.5 ab	200.7 b	5.8 a	7.8 a

[1]Reproduction and vigor are numerical estimations where 1 is low and 9 is high.
[2]Values followed by the same letters are not significantly different ($P<0.05$) by the multiple range comparison tests.

However, the poorest fill was found on the north side of the plant, probably due to wind direction during pollination. Winds seldom blew from the north during pollination.

Utricle fill was also examined in relation to the distrance of the female from the male pollen-producing plants. Each numbered female was replicated three times, and the individual rows were spaced at different distances from the male (fig. 2). Distance of the female from the male did not have a significant influence on utricle fill (table 4B). This means that the orchard design was adequate for pollination.

Utricle fill was also evaluated in relation to the different numbered females. The female parent did have a significant effect on utricle fill (table 4C). Females 1-01 and 4-04 had the best fill. A good fill was also found for numbers 11-37 and 8-56. Female 1-20 had the poorest fill.

In 1982 a total of 363.7 pounds (165 kg) of clean seed was harvested from the 3.1 acre (1.3 ha) orchard (table 5). This averaged 117.3 lb per acre (131.5 kg/ha) of clean seed considering both replications of seedlings and clones.

The two replications of seedlings produced only 127.2 lb (57.7 kg) of clean seed, which represented only 35 percent of the total production for the entire orchard. The two replications of clones produced 236.5 lb (107.3 kg) of clean seed, and represented 65 percent of the seed production from the entire orchard. The northeast replication of the clones was the most productive with 144.3 lb (65.5 kg) of clean seed. It is interesting to note that each replication of clones produced more seed than either of the two replications of seedlings. Seed production in 1982 was significantly greater ($P<0.01$) for the clones than for the seedlings (table 6A). A comparison of seed production was made between the two replications of clones. Seed production was significantly

Table 3.--"T" test comparison of height, crown, reproduction, and vigor of male vs female cloned plants and of female clones vs female seedlings.

83 male vs 407 female clones				
	Male (83 clones)	Female (407 clones)	Significance[1]	Probability
Height (cm)	117.5	107.7	NS	0.05
Crown (cm)	195.0	202.7	NS	.10
Reproduction[2]	5.9	5.5	NS	.10
Vigor[2]	7.8	7.8	NS	.90

407 female clones vs 220 female seedlings			
	Clones (407 female)	Seedlings (220 female)	Significance
Height (cm)	110.6	107.7	*
Crown (cm)	210.5	202.7	*
Reproduction[2]	5.5	5.6	NS
Vigor[2]	8.1	7.8	*

[1]NS = Not significant, * = $P<.05$
[2]Reproduction and vigor are numerical estimations where 1 is low and 9 is high.

Table 4.--Percent seed fill evaluated by analysis of variance (with multiple range tests). Seed fill was evaluated in relation to position on the plant (A), distance from male (B), and different numbered females (C).

A

Seed fill by position on plant

Position	Top	East	South	West	North	Significance[1]
% Fill	60.4	52.4	50.6	48.0	38.0	NS

B

Seed fill by parent and row (distance from males)

Each female occurred three times in each replication of clones. This test was done to find out if there was a difference in fill within the three rows since they occurred at different distances from the male plants (fig. 2).

Female	$\overline{X}$	Range	$F_{2,6}$	Significance
1-01	72.8	68-81	1.4	NS
4-04	64.1	39-78	1.4	NS
11-37	56.6	43-70	.3	NS
8-56	55.6	42-69	1.1	NS
6-04	43.0	18-59	1.7	NS
1-20	16.7	0-39	2.9	NS

C

Seed fill for different numbered females

F = 33.6**

Number female	1-01	4-04	11-37	8-56	6-04	1-20
% fill	72.8	64.1	56.6	55.6	43.0	16.7

[1] NS = not significantly different, ** = P<0.01, lines under mean values indicate no significant difference.

greater in the northeast replication of clones (table 6B). This can probably be explained by the soil difference discussed earlier. Seed production for the two replications of seedlings was found to be not significantly different (table 6C).

Seed production per row (11 plants) in 1982 was examined by individual numbered female for the two replications of clones. The seed production from the two replications of clones was produced in large part by two of the six females, 11-37 and 1-01 (table 7). These two females accounted for 75 percent of the total seed production from the two replications of clones. Statistically, females 11-37 and 1-01 produced significantly more seed than the other females. Female plants of 1-20 produced the smallest amount of clean seed (table 7). We point out, however, that the orchard is still young and the other females may produce more later. It should be remembered that some plants were producing only for the first year in 1982 whereas others had produced for 2 years. Furthermore, to maintain a broader genetic base, all females should be included in the orchard. Selection of female plants was based on forage production, tendency to be evergreen, and growth form, as well as seed production.

Table 5.--Clean seed weights for seedlings and clones in 1982.

Type of Seed	Weight (Pounds)	Pounds per acre
Seedling:		
Northwest replication	72.6	
Southeast replication	54.6	
Total	127.2	82.1
Clone:		
Southwest replication	92.2	
Northeast replication	144.3	
Total	236.5	152.6
Total for orchard	363.7	117.3

Table 6.--X^2 analyses of seed production, 1982. A comparison of clones and seedlings-A, two replications of clones, northeast vs southwest-B, two replications of seedlings, northwest vs southeast-C.

		Observed	Expected
A.	Clones	236.5	181.8
	Seedlings	127.2	181.8
		$X^2 = 32.8$, DF = 1, $P \ll 0.01$	
B.	Northeast clones	144.3	121.8
	Southwest clones	99.2	121.8
		$X^2 = 8.3$, DF = 1, $P < .01$	
C.	Northwest seedlings	72.6	63.6
	Southeast seedlings	54.6	63.6
		$X^2 = 2.5$, DF = 1, $.3 > P > .2$ (NS)	

Table 7.--Seed production per row (11 plants) for clones in 1982. Seed production is listed by numbered females for each replication.

Numbered female	Southwest replication	Northeast replication
11-37	[1]14.3 a	[1]18.4 a
1-01	10.0 b	16.3 a
6-04	3.6 c	5.7 b
8-56	1.3 d	2.8 c
4-04	0.6 de	2.0 cd
1-20	0.4 e	0.8 d

[1]Letter differences signify mean differences at $P<0.05$. Bartlett's test for homogeneity of variances did not allow combining of blocks.

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PUBLICATIONS CITED

Gerard, J. B. Factors affecting fruit fill and seed germination of fourwing saltbush (*Atriplex canescens* [Pursh] Nutt.). In: Hyder, D. N., ed. Proceedings, first international rangeland congress; 1978 August 14-18; Denver County, Denver, CO: Society for Range Management; 1978: 403-405.

McArthur, E. D. Environmentally induced changes of sex expression in *Atriplex canescens*. Heredity. 38: 97-103; 1977.

McArthur, E. D.; Plummer, A. P.; Van Epps, G. A.; Freeman, D. C.; Jorgensen, K. R.; Producing fourwing saltbush seed in seed orchards. In: Hyder, D. N., ed. Proceedings, first international rangeland congress; 1978 August 14-18; Denver County, Denver, CO: Society for Range Management; 1978: 406-410.

Woolf, C. M. Principles of biometry. Princeton, NJ: D. Van Nostrand Company [Inc.]; 1968. 359 p.

[2]Federal funds for wildlife restoration from Pittman-Robertson Project W-82-R facilitated this study.

In: Tiedemann, Arthur R.; McArthur, E. Durant; Stutz, Howard C.; Stevens, Richard; Johnson, Kendall L., compilers. Proceedings--symposium on the biology of *Atriplex* and related chenopods; 1983 May 2-6; Provo, UT. General Technical Report INT-172. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 309 p.

Section 6. Animal Relationships

POTENTIAL USE OF FOURWING SALTBUSH AND OTHER DRYLAND SHRUBS FOR UPLAND GAME BIRD COVER IN SOUTHERN IDAHO

Nancy Shaw, Alan Sands and Dale Turnipseed

ABSTRACT: Twenty-nine accessions of fourwing saltbush (Atriplex canescens [Pursh] Nutt.) were transplanted on a semiarid southern Idaho site to determine adaptability, and to evaluate which accessions best met upland game cover criteria. A cover index value was computed for each shrub. All accesssions of fourwing saltbush appeared to be well adapted to the site; structural characteristics varied widely. Growth rates and habits of fourwing saltbush, big sagebrush (Artemisia tridentata Nutt.), silver sagebrush (A. cana Pursh), winterfat (Ceratoides lanata [Pursh] J.T. Howell), rubber rabbitbrush (Chrysothamnus nauseosus [Pallas] Britt.), and forage kochia (Kochia prostrata [L.] Schrad.) were also compared. Use of these shrubs provides an opportunity to increase vertical stratification to meet the various cover needs of upland game birds.

INTRODUCTION

Ring-necked pheasants (Phasianus colchicus L.), California quail (Callipepla californica Shaw), and gray partridge (Perdix perdix L.) are common upland game birds associated with irrigated agricultural lands in southern Idaho. The recreation and esthetic values provided by these birds are substantial. Statewide, pheasant hunting alone accounts for an estimated 500,000 hunter-days annually, most of which occur in southern Idaho (Idaho Department of Fish and Game 1983).

The habitat needs of these birds are not entirely fulfilled by croplands. Farming practices are intensive; fence rows and other waste areas are cleared of natural vegetation, and fields are frequently fallow during fall and winter. Consequently, unfarmed habitats are crucial to upland game birds at certain times of the day and season. Shrub/grass habitats are particularly attractive to quail and pheasants. Shrubs are the focal point of all California quail activity (Leopold 1977). Pheasants use shrub-covered areas intensively during the fall and winter (Salinger 1950; Swanson and Yocum 1958; Hansen and Labisky 1974; Morton 1971; Gates and Hale 1974; Snyder 1982). Early pheasant nesting frequently occurs in shrub-grass cover types (Bartmann 1969; Gates and Hale 1975). Shrub cover is considered relatively unimportant to gray partridge, but they are often associated with shrubs during severe weather (Weigand 1980; Mendel and Peterson 1983).

Although it is widely understood that wildlife respond to the structural features of their environment, little work has been done to describe the physical characteristics of individual shrubs used by pheasants and quail. It is generally believed that shrubs that are low growing (2 to 8 feet [0.6 to 2.4 m] in height), broadly crowned, and densely branched with lateral branches close to the ground provide better cover (thermal and hiding) than upright, sparsely branched shrubs (Leopold 1977; Adkins 1980).

Fourwing saltbush (Atriplex canescens [Pursh] Nutt.) has been studied since 1964 as an upland game cover plant, and promoted for that use since 1968 (California Department of Fish and Game 1968; McKibben and Slayback 1977; California Department of Fish and Game and USDA Soil Conservation Service 1980). Fourwing saltbush is adapted to arid sites, occurs over an extensive region, develops rapidly from seed or transplants, and can be planted with other species (Plummer and others 1966; Van Epps and McKell 1977). It has shown considerable interaccessional variation in a number of characteristics including size, growth rate, and growth form (Plummer and others 1966; Stutz and others 1975; McArthur and others 1983). Fourwing saltbush has also been found to significantly increase the production of grass growing in association with shrubs (Rumbaugh and others 1982), a situation which may enhance nesting cover for pheasants (Wood and Brotherson 1981).

We evaluated the structural characteristics of 29 accessions of fourwing saltbush (table 1) at a site in Twin Falls County, Idaho, to determine which best met upland bird winter cover criteria. We also compared differences in growth rates and growth habits of selected fourwing saltbush accessions, other introduced shrub species and accessions, and native Wyoming big sagebrush (Artemisia tridentata Nutt. ssp. wyomingensis Beetle and Young) at this site (table 2). Shrub accessions originated from seed collected from native stands in seven western states (fig. 1).

Shrub selection trials are part of a cooperative program between the USDI Bureau of Land Management, Idaho Department of Fish and Game, and the USDA Forest Service, Intermountain Forest and Range Experiment Station, to enhance wildlife habitat on public lands in Idaho.

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Table 1.--Location of native stands of fourwing saltbush accessions grown at Bell Rapids site.

Accession	Elevation	Latitude	Vegetation type
	Ft	° N	
Black Mtn., Sevier County, UT	6,230	38°50'	Pinyon-juniper, sagebrush
Tuba City, Coconino County, AZ	4,990	36°08'	Fourwing saltbush
St. George, Washington County, UT	2,760	37°06'	Fourwing saltbush
Hanksville, Wayne County, UT	4,300	38°23'	Shadscale, greasewood
Ephraim, Sanpete County, UT	5,510	39°22'	Fourwing saltbush, greasewood
Emery, Emery County, UT	6,200	38°54'	Gardner saltbush, fourwing saltbush
Reno, Washoe County, NV	4,490	38°31'	Fourwing saltbush, shadscale
Delta, Delta County, CO	4,990	38°40'	Fourwing saltbush
Keams Canyon, Navajo County, AZ	6,300	35°50'	Basin big sagebrush, fourwing saltbush
Rincon Blanco, Rio Arriba County, NM	7,870	36°30'	Pinyon-juniper
Escalante, Garfield County, UT	5,810	37°44'	Fourwing saltbush
Randlett, Uintah County, UT	4,790	40°12'	Fourwing saltbush
Pine Valley, Washington County, UT	5,300	38°41'	Pinyon-juniper
Lund, Iron County, UT	5,080	38°02'	Fourwing saltbush, greasewood
Fayette, Sanpete County, UT	5,050	39°14'	Pinyon-juniper
Grand Junction, Mesa County, CO	4,590	39°05'	Fourwing saltbush
Reynolds Creek, Owyhee County, ID	4,000	43°16'	Fourwing saltbush, Wyoming big sagebrush
Timpanogas, Wasatch County, UT	6,000	40°22'	Fourwing saltbush, mountain big sagebrush
Kanab, Kane County, UT	4,990	37°02'	Fourwing saltbush
Cedar City, Iron County, UT	5,810	34°40'	Pinyon-juniper
San Rafael Swell, Emery County, UT	5,710	39°00'	Pinyon-juniper
Desert Range Experiment Station, Millard County, UT	5,310	38°37'	Shadscale, greasewood
Gunnison, Gunnison County, CO	7,680	38°32'	Shadscale, fourwing saltbush
Manila, Daggett County, UT	6,820	41°00'	Pinyon-juniper, mountain big sagebrush
Panaca, Lincoln County, NV	4,660	37°40'	Northern desert shrubs
Huntington, Emery County, UT	5,900	39°20'	Pinyon-juniper
Jackson Springs, Washington County, UT	5,080	37°24'	Pinyon-juniper
Bliss, Gooding County, ID	3,260	42°56'	Basin big sagebrush, fourwing saltbush
Jericho, Juab County, UT	5,248	39°40'	Fourwing saltbush

Table 2.--Performance of six shrub accessions at Bell Rapids study site.[1]

Species/Accession	Elevation	Latitude	Vegetation type	Survival	Height	Crown
	Ft	° N		Percent	---Inches---	
Artemisia cana Pursh. ssp. cana. Decker, Bighorn County, Mont.	3,510	44°58'	Silver sagebrush, fourwing saltbush	95	25	47
Artemisia tridentata Nutt. ssp. vaseyana (Rydb.) B. Boi. Carey, Blaine County, Idaho	4,790	43°19'	Mountain big sagebrush	93	34	29
Artemisia tridentata Nutt. ssp. wyomingensis Beetle and Young. Bell Rapids, Twin Falls County, Idaho[2]	3,080	42°41'	Wyoming big sagebrush	--	15	14
Ceratoides lanata (Pursh) J.T. Howell. Hatch, Garfield County, Utah	6,990	37°38'	Mountain big sagebrush	70	22	35
Chrysothamnus nauseosus (Pallas) Britt. ssp. albicaulis (Nutt.) Rydb. Marysvale, Piute County, Utah	5,840	38°28'	Wyoming big sagebrush	60	34	41
Chrysothamnus viscidiflorus (Hook.) Nutt. ssp. lanceolatus (Nutt.) Greene. Decker, Bighorn County, Mont.	3,510	45°01'	Silver sagebrush, Wyoming big sagebrush	26	13	20

[1] Survival and growth of transplanted accessions sampled following fifth growing season.
[2] Native stand of mature plants.

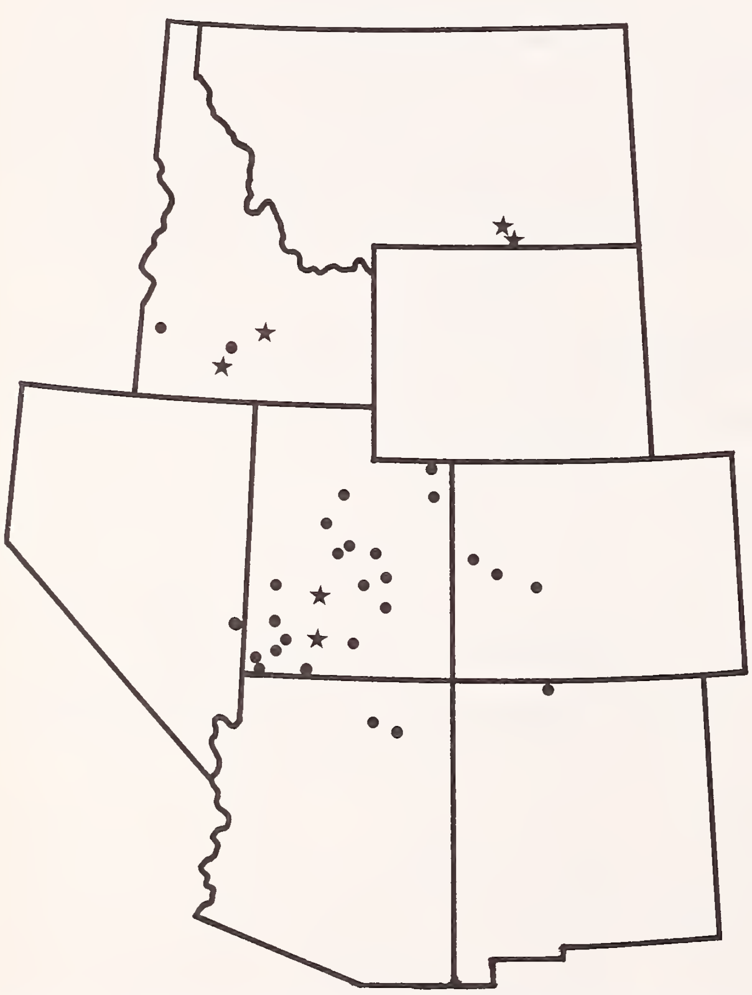

Figure 1.--Map showing original collection sites of fourwing saltbush and other shrub accessions grown at Bell Rapids site.

STUDY AREA

The Bell Rapids study area is located on the Snake River Plains approximately 13 miles (21 km) northwest of Buhl in Twin Falls County, Idaho. Topography of the area is undulating. Elevation is 3,440 feet (1 050 m). The fine-silty to fine-loamy soils are well drained and approximately 60 inches (152 cm) deep with a lime silica cemented duripan at 34 to 40 inches (86 to 102 cm). Prior to disturbance, the area was representative of the Wyoming big sagebrush/thurber needlegrass (Stipa thurberiana [Piper in Scribn.]) habitat type (Hironaka and others 1983). Most of the area has been converted to irrigated agricultural land. Scattered tracts of public land represent the only unfarmed habitats in the area. Vegetation on these tracts is currently dominated by Wyoming big sagebrush/cheatgrass (Bromus tectorum L.), cheatgrass, or crested wheatgrass (Agropyron cristatum [L.] Gaertn.).

Climate of the area is semiarid. Average annual precipitation is estimated at 9.1 inches (23 cm), based on the long-term average at Bliss, Idaho, 13 miles (21 km) north of the study site. During the 1978-83 study period, annual precipitation averaged 10.2 inches (26 cm). Approximately 35 percent of the precipitation occurs between April 1 and September 31. The frost-free season averages 148 days. From 1978 to 1983 the average minimum daily temperature in January was 20.5° F (-6.4° C) while the lowest recorded temperature during this period was -14.0° F (-25.8° C). Winter snow cover is normally light and intermittent.

METHODS

Utricles of fourwing saltbush were dewinged, clipped, leached in running water, and stratified for 2 weeks. Seedlings were propagated in Leach tubes. Four or five utricles were planted in each tube and seedlings were thinned to one per tube after the first secondary leaves developed. After 10 weeks of growth, seedlings were hardened off by gradually increasing their exposure to ambient conditions.

Field sites were cleared of vegetation and tilled prior to planting. Seedlings were transplanted in March 1978. The fourwing planting site was divided into four blocks which were subdivided into row plots. Ten seedlings of each accession were planted in a randomly selected row plot in each block. Seedlings of some accessions were planted in only two or three row plots when propagation problems or a lack of seed limited the number of transplants produced. Seedlings were planted on 6 foot (1.8 m) centers. Additional shrub species and accessions were also propagated and transplanted in a similar manner. These were transplanted adjacent to the fourwing saltbush planting or at one of two additional planting sites located within a 3-mile (4.6-km) radius. Hand and mechanical weeding were employed to reduce competition during the first 2 years following transplanting.

Winter cover characteristics provided by the 29 fourwing saltbush accessions and native Wyoming big sagebrush were evaluated in February 1983. Parameters sampled were: survival; height; crown spread; growth type (0=erect, 1=semierect, 2=diffuse); growth form (0=open treelike canopy, 1=many branches, canopy somewhat open, 2=closed canopy, dense branches); leaf retention (0=none to poor, 4=excellent); and seed retention (0=none to poor, 4=excellent). Each surviving fourwing saltbush shrub was sampled. Wyoming big sagebrush data were obtained from 40 mature plants selected randomly from a native stand adjacent to the fourwing saltbush plots.

A cover index value was also computed for each shrub. The parameters judged to contribute substantially to the quality of cover provided by individual shrubs were given weighted values (crown diameter=20 percent, growth type=30 percent, growth form=30 percent, leaf retention= 20 percent). The following formula was used:

$$\text{Cover Index} = \frac{\text{crown diameter (inches)}}{78.4} \times 20 + \frac{\text{growth type score}}{3} \times 30 + \frac{\text{growth form score}}{3} \times 30 + \frac{\text{leaf retention score}}{4} \times 20.$$

Plants with high scores for each parameter received scores approaching 100. Plants greater than 78.4 inches (200 cm) in crown diameter could attain cover index scores greater than 100, provided the other values were at or near maximum. Height was not included in the index as all accessions were considered to provide adequate vertical cover. Seed retention is reported separately from the cover index values for each accession as the plants are dioecious. High seed retention was judged to significantly improve the quality of cover provided by female plants in winter and should be considered with the cover index in evaluating individual accessions.

Means of all parameters sampled were computed for each accession. Height, crown, and cover index values were analyzed using analysis of variance techniques. Mean separations for cover index values were performed with the Duncan Multiple Range Test (Steele and Torrie 1960). Growth rates of the fourwing saltbush and other shrub accessions were derived from annual maximum height and crown measurements of each shrub. Data were recorded annually, beginning in 1978 in late summer when vegetative growth had diminished.

RESULTS

Fourwing Saltbush Accessions

Fourwing saltbush appears to be well adapted to the Bell Rapids site. Plants of all accessions are vigorous, and little mortality has occurred since the first growing season following transplanting (table 3). There were significant ($P < 0.05$) differences among accessions in height, crown, and cover index values. No accession exhibited consistently high scores in all categories, although the Black Mountain, Sevier County, Utah, and Tuba City, Coconino County, Arizona, accessions did score strongly in all traits and received the highest cover index values.

The Rincon Blanco, Rio Arriba County, New Mexico, accession ranked highest in combined leaf and seed retention. This accession is from the parent material used to develop the 'Rincon' fourwing selection recently released for commercial production by the USDA Soil Conservation Service and cooperating agencies (McArthur and others 1982). It is likely that the 'Rincon' selection would score higher as an upland game bird cover plant than the parent stock. The 'Rincon' selection generally is less erect, has more foliage, and produces more seed than the parent stock (McArthur and others 1983).

The very open growth form of the gigas diploid Jericho accession, Juab County, Utah, contributed to its low cover index value. Mean height of this accession was greater than that of any other accession. Large size and open growth are characteristic of this accession on its native site and in other common gardens (Stutz and others 1975; McArthur and others 1983).

Table 3.--Cover characteristics of 29 accessions of fourwing saltbush and native Wyoming big sagebrush at Bell Rapids.

Accession	N[1]	Survival	Height	Crown	Growth type[2]	Growth form[3]	Leaf retention[4]	Seed retention[4]	Cover index[5]
		Percent	--Inches--						
Fourwing saltbush									
Black Mountain	12	60	39	84	1.8	1.4	2.9	2.3	84.7 ± 23.4[a]
Tuba City	21	53	42	77	1.9	1.4	3.1	1.7	84.6 ± 15.2[a]
St. George	6	75	42	69	1.2	2.0	3.5	2.7	82.6 ± 9.6[ab]
Hanksville	12	60	35	69	2.0	0.9	3.6	2.0	79.3 ± 7.5[ab]
Ephraim	11	55	38	71	1.9	1.1	3.0	1.8	78.0 ± 19.5[abc]
Emery	16	67	37	74	1.6	1.1	3.6	1.8	72.9 ± 21.0[abc]
Reno	11	55	31	54	1.8	1.4	3.3	1.0	77.9 ± 14.5[abc]
Delta	24	80	39	73	1.9	1.0	3.0	1.5	77.2 ± 11.6[abcd]
Keams Canyon	14	70	35	63	1.7	1.0	3.4	2.0	73.5 ± 10.0[abcde]
Rincon Blanco	6	75	41	68	1.7	1.0	3.0	3.5	72.2 ± 16.4[abcde]
Escalante	27	75	31	63	1.9	1.0	2.4	1.5	72.1 ± 16.0[abcde]
Randlett	22	73	40	67	1.5	1.1	3.4	1.5	71.7 ± 21.8[abcde]
Pine Valley	22	56	30	63	1.4	1.2	3.1	2.7	71.1 ± 18.6[bcde]
Lund	30	77	30	52	1.6	1.1	3.3	1.5	70.5 ± 14.7[bcdef]
Fayette	26	72	35	65	1.8	1.0	2.5	1.3	70.2 ± 18.6[bcdef]
Grand Junction	12	71	46	77	1.6	0.8	3.0	2.0	69.6 ± 15.9[bcdefg]
Reynolds Creek	9	60	34	63	1.9	1.1	1.7	1.9	69.4 ± 18.3[bcdefg]
Timpanogas	30	75	36	65	1.7	0.9	2.3	1.4	68.2 ± 14.3[bcdefg]
Kanab	20	71	39	64	1.5	0.9	3.0	1.8	68.0 ± 22.3[bcdefg]
Cedar City	23	64	38	62	1.6	1.0	2.9	2.0	68.0 ± 15.7[bcdefg]
San Rafael Swell	19	53	35	68	1.6	0.9	2.7	1.9	67.9 ± 18.2[bcdefg]
Desert Range Experiment Station	14	78	34	63	1.6	0.9	2.9	1.6	67.8 ± 16.2[bcdefg]
Gunnison	26	65	33	54	1.8	0.8	2.7	1.3	66.5 ± 11.7[bcdefg]
Manila	14	39	41	63	1.6	0.9	2.7	0.9	65.9 ± 10.6[bcdefg]
Panaca	24	80	35	68	1.6	0.9	2.7	1.9	62.4 ± 18.2[efg]
Huntington	27	74	43	70	1.3	0.4	2.9	1.3	57.0 ± 7.5[fg]
Jackson Springs	16	80	39	78	1.8	1.0	3.4	2.2	56.5 ± 20.0[g]

Con.

Table 3. Con.

Accession	N[1]	Survival	Height	Crown	Growth type[2]	Growth form[3]	Leaf retention[4]	Seed retention[4]	Cover index[5]
		Percent	--Inches--						
Fourwing saltbush (con.)									
Bliss	38	95	32	65	1.1	0.1	2.3	2.3	45.3 ± 8.4^{h}
Jericho	7	78	54	74	0.9	0.4	2.1	2.8	38.9 ± 27.9^{i}
Wyoming big sagebrush									
Bell Rapids	40	--	14	15	0.2	1.4	1.1	0.0	33.7 ± 9.2

[1] N = number of surviving plants.
[2] Growth type (0=erect, 1=semi erect, 2=diffuse).
[3] Growth form (0=open treelike canopy; 1=canopy somewhat open, many branches; 2=closed canopy, dense branches).
[4] Leaf or seed retention (0=none to poor, 1=poor, 2=fair, 3=good, 4=excellent).
[5] Mean cover index $\pm$ standard deviation. Means followed by the same letter superscript are not significantly different at $P<0.05$ level of significance using Duncan's multiple range test.

The Bliss accession, Gooding County, Idaho, collected from cliffs on the north bank of the Snake River approximately 10 miles (16 km) east of the study site, exhibited excellent survival, but received a low cover index rating due to its open canopy and moderate crown size. Other native populations of fourwing saltbush possessing more desirable cover characteristics have been identified growing on the floodplain of the Snake River in the Bell Rapids area.

Within accessions, individual plants frequently differed in cover characteristics, reflecting the inherent variation within the species. Similar variation would be expected in cover plantings produced from seed. Cover quality and plant uniformity might be increased by collecting seed only from selected plants with desirable cover characteristics. Variation would still be expected because the shrubs are open pollinated. Cover quality might be more reliably increased by establishing plantings from rooted cuttings taken from plants with high cover index values. Techniques for the propagation of fourwing saltbush from cuttings are described by Wiesner and Johnson (1977). In addition, the ratio of female to male plants can be regulated by this method to maximize the number of seed-producing plants (McArthur and others 1978).

Other Shrubs

Although low mean annual precipitation limits the number of species that can be selected to provide wildlife cover on nonirrigated lands in southern Idaho, several species have exhibited good survival (table 2) and vigor when grown in species selection plots at the Bell Rapids site. Not all of these species would provide winter cover for upland game birds. They could be included in plantings to increase the diversity of plants and vertical stratification of the vegetation to meet other habitat needs of upland game birds and to provide perching and nesting habitat for other bird species.

The white rubber rabbitbrush (Chrysothamnus nauseosus [Pallas] Britt. ssp. albicaulis [Nutt.] Rydb.) accession consists of relatively large shrubs with an open, erect growth habit. They do not retain seed or leaves through the winter. The accession does provide height which is lacking in the native Wyoming big sagebrush. Survival and vigor of the mountain rubber rabbitbrush (Chrysothamnus viscidiflorus [Hook] Nutt. ssp. lanceolatus [Nutt.] Greene) accession is low, indicating poor adaptability to the site.

The winterfat (Ceratoides lanata [Pursh] J.T. Howell) accession is a foothill variety from Hatch, Garfield County, Utah. Its mean height at the Bell Rapids site is 22 inches (56 cm). Growth habit is open and spreading, but grass tends to grow within and around the crown of the plant, possibly increasing its value as nesting cover.

Wyoming big sagebrush received a lower cover index value than any fourwing accession rated (table 3). Its mean crown diameter was smaller than any species or accession examined (fig. 2). Nevertheless, when cover is limited on adjacent agricultural habitats, Wyoming big sagebrush/grass habitats are used intensively by pheasants during the winter in southern Idaho. It is our opinion that this type of habitat provides adequate daytime hiding cover but a fourwing/grass habitat would be superior in moderating the effects of severe weather and would be selected by pheasants during adverse conditions. We do not advocate the

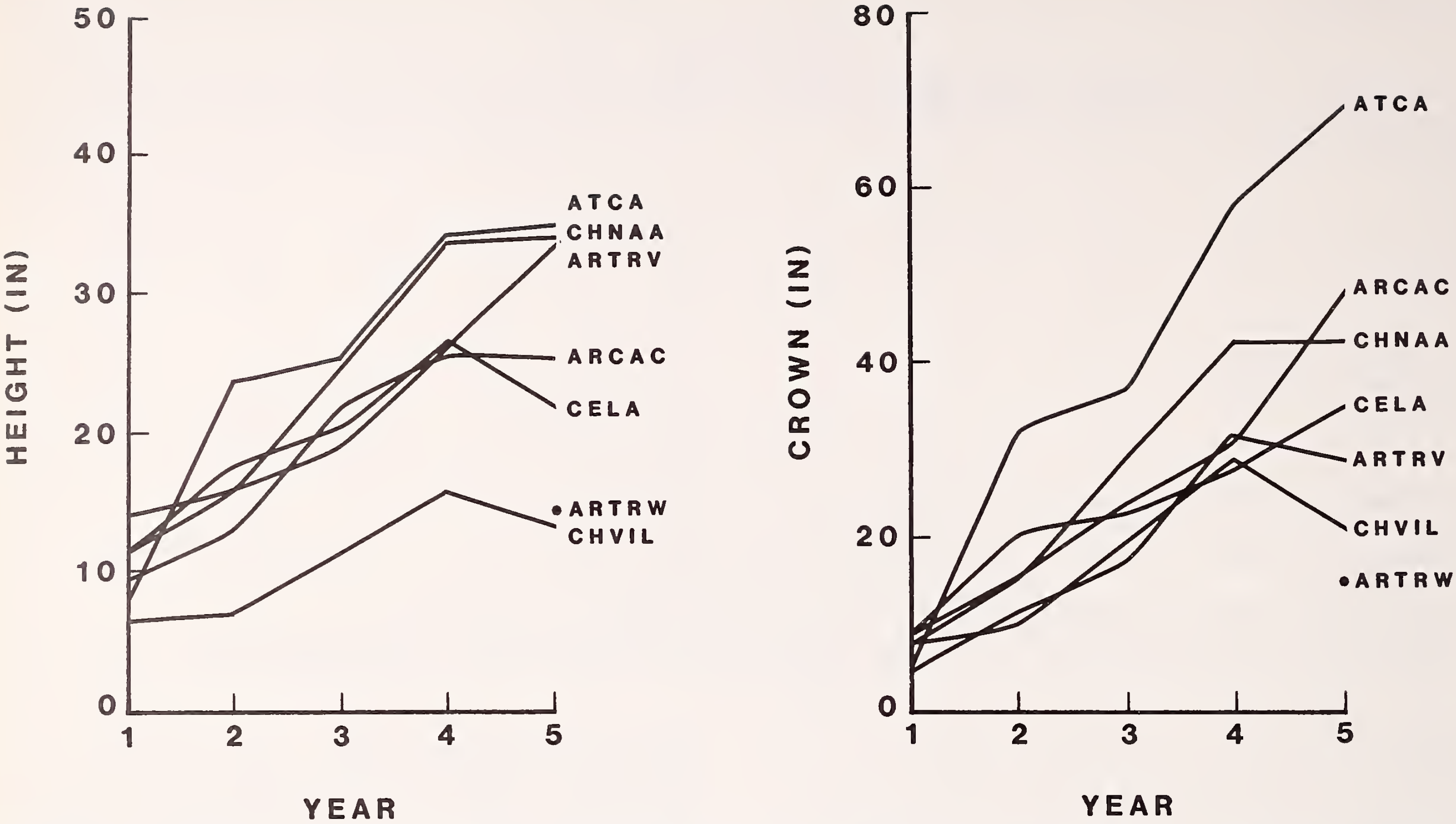

Figure 2.-- Height and crown development of selected shrub accessions at Bell Rapids. Fourwing saltbush data are means for accessions 1 through 12 (table 1). Remaining accessions are identified in table 2. ARCAC=Artemisia cana cana, ARTRV=Artemisia tridentata vaseyana, ARTRW=Artemisia tridentata wyomingensis[1], ATCA=Atriplex canescens, CELA=Ceratoides lanata, CHNAA=Chrysothamnus nauseosus albicaulis, CHVIL= Chrysothamnus viscidiflorus lanceolatus.

[1]Only mature plants were measured.

removal of native sagebrush stands to plant fourwing or other shrubs until comparative use evaluations indicate that other shrubs are clearly superior to native sagebrush as upland game cover. Present efforts are directed toward the enhancement of cover on depleted shrublands.

Mountain big sagebrush (Artemisia tridentata Nutt. ssp. vaseyana [Rydb.] B. Boi.), and silver sagebrush (A. cana Pursh ssp. cana) did not receive cover index ratings. They would have likely scored higher than the Wyoming big sagebrush based on their crown development (fig. 2) and ocular assessment. Survival (table 2) and growth rates (fig. 2) of both species were very good in spite of the significant differences between their native sites and the study area. The ability of silver sagebrush to sprout after fire (Beetle 1960) increases its potential utility as an upland game bird cover plant.

Height and crown development for each of these shrub species and a composite of the 12 highest ranking fourwing saltbush accessions are illustrated in fig. 2. Following the second growing season, the mean crown diameter of the 12 fourwing saltbush accessions was about 65 percent greater than that of any of the other shrub accessions. After 5 years, this figure had dropped to about 55 percent. None of the other shrubs tested or the native Wyoming big sagebrush provide the combination of crown diameter, dense canopy cover, and rapid growth as did the fourwing saltbush accessions. The production of significant amounts of cover following two growing seasons make fourwing saltbush particularly valuable as a cover plant on burns, waste areas, or disturbed sites.

An additional shrub, forage kochia (Kochia prostrata [L.] Schrad.) has received limited testing at the Bell Rapids site. This shrub provides dense, low growing cover, similar to that provided by alfalfa. However, it retains its structure better through the winter and spring months. It may have significant value as a pheasant nesting cover plant.

CONCLUSIONS

A variety of accessions of fourwing saltbush are well adapted to the semiarid lands in southern Idaho. They readily established from transplanting without irrigation and grew rapidly. Populations may be selected that provide a dense,

heavily branched canopy and tend to retain their seeds and leaves late into the winter. Local seed sources or sources from higher elevations are recommended (Van Epps 1975; McArthur and others 1983). Mixed plantings of fourwing saltbush, big sagebrush, silver sagebrush, white rubber rabbitbrush, winterfat, forage kochia, and grasses provide an opportunity to diversify upland game bird cover without irrigation. These plantings can provide important habitat for upland game birds and other wildlife when cover is lacking on adjacent irrigated agricultural lands.

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PUBLICATIONS CITED

Adkins, J. Upland game habitat development evaluation. Completion Rep. Proj. W-70-R-19, Job 1. Olympia, WA: Washington Department of Game; 1980. 163 p.

Bartmann, R. Pheasant nesting on soil bank land in northern Utah. J. Wildl. Manage. 33(4): 1020-1023; 1969.

Beetle, A. A. A study of sagebrush. The section Tridentatae of Artemisia. Bull. 368. Laramie, WY: University of Wyoming, Agricultural Experiment Station; 1960. 83 p.

California Department of Fish and Game. Atriplex: a cover plant for wildlife. Game Management Leaflet 11. Sacramento, CA: California Department of Fish and Game; 1968. 11 p.

California Department of Fish and Game; USDA Soil Conservation Service, Upland Game Report 1964-80. Completion Rep. Proj. W-47-R-28, Job 1. 1980. 158 p.

Gates, J. M.; Hale, J. B. Seasonal movement, winter habitat use, and population distribution of an east central Wisconsin pheasant population. Tech. Bull. 76. Madison, WI: Wisconsin Department of Natural Resources; 1974. 70 p.

Gates, J. M.; Hale, J. B. Reproduction of an east central Wisconsin pheasant population. Tech. Bull. 85. Madison, WI: Wisconsin, Department of Natural Resources; 1975. 70 p.

Hansen, W. R.; Labisky, R. F. Association of pheasants with vegetative types in east-central Illinois. Trans. N. Amer. Wildl. Conf. 29: 295-306; 1974.

Hironaka, M.; Fosberg, M. A.; Winward, A. H. Sagebrush-grass habitat types of southern Idaho. Bull. 35. Moscow, ID: University of Idaho; 1983. 44 p.

Idaho Department of Fish and Game. Upland game - 1981-1985 species management plan. Boise, ID: Idaho Department of Fish and Game; 1983. 67 p.

Leopold, A. S. The California quail. Berkeley: University of California Press; 1977. 281 p.

McArthur, E. D.; Plummer, A. P.; Van Epps, G. A.; Freeman, D. C.; Jorgensen, K. R. Producing fourwing saltbush in seed orchards. In: Hyder, D. N., ed. Proceedings first international rangeland congress. Denver, CO: Society for Range Management; 1978: 406-410.

McArthur, E. D.; Hassell, W. G.; Stevens, R.; Davis, J. N.; Stranathan, S. E.; Noller, G. L.; Tiedemann, A. R.; Goodrich, S. K. Notice of naming and release of 'Rincon' fourwing saltbush (Atriplex canescens) for wildlife and livestock range and disturbed land reclamation. Washington, DC: U.S. Department of Agriculture, Soil Conservation Service; 1982. 5 p.

McArthur, E. D.; Stevens, R.; Blauer, A. C. Growth performance comparisons among 18 accessions of fourwing saltbush (Atriplex canescens) at two sites in central Utah. J. Range Manage. 36(1): 78-81; 1983.

McKibben, L.; Slayback, R., compilers. Establishing woody plants for upland game habitat in California. Wildlife Habitat Leaflet 6. Sacramento, CA: California Department of Fish and Game, U.S. Department of Agriculture, Soil Conservation Service; 1977. 7 p.

Mendel, G. W.; Peterson S. R. Management implications of gray partridge habitat use on the Palouse Prairie, Idaho. Wildl. Soc. Bull. 11(4):348-355; 1983.

Morton, W. B. Evaluation of habitat improvement programs for pheasants in eastern Colorado. Fort Collins, CO: Colorado State University; 1971. 122 p. Thesis.

Plummer, A. P.; Monsen, S. B.; Christensen, D. R. Fourwing saltbush, a shrub for future game ranges. Publ. 66-4. Salt Lake City, UT: Utah Department of Fish and Game; 1966. 12 p.

Rumbaugh, M. D.; Johnson, D. A.; Van Epps, G. A. Forage yield and quality in a Great Basin shrub, grass, and legume pasture experiment. J. Range Manage. 35(5): 604-609; 1982.

Salinger, H. E. Factors affecting pheasant production on the irrigated lands in southern Idaho. Moscow, ID: University of Idaho; 1950. 103 p. Thesis.

Snyder, W. Evaluation of nesting cover preferences of pheasants in relation to wheat farming methods. Completion Rep. Proj. W-37-R-35, Job 22. Denver, CO: Colorado Division of Wildlife; 1982. 57 p.

Steele, R. G. D.; Torrie, J. H. Principles and procedures of statistics. New York: McGraw-Hill; 1960.

Stutz, H. C.; Melby, J. M.; Livingston, G. K. Evolutionary studies in Atriplex: a relic gigas diploid population of Atriplex canescens. J. Bot. 62: 236-245; 1975.

Swanson, C. V.; Yocum, C. F. Upland game bird populations in relation to cover and agriculture in southeastern Washington. Trans. N. Amer. Wildl. Conf. 23: 277-290; 1958.

Van Epps, G. A. Winter injury to fourwing saltbush. J. Range Manage. 28: 157-159; 1975.

Van Epps, G. A.; McKell, C. M. Shrubs plus grass for livestock forage: a possibility. Utah Sci. 38: 75-78; 1977.

Weigand, J. P. Ecology of the hungarian partridge in north-central Montana. Wildl. Monog. 74. Wildl. Soc. 106 p.

Wiesner, L. E.; Johnson, W. J. Fourwing saltbush (Atriplex canescens) propagation techniques. J. Range Manage. 30(2): 154-156; 1977.

Wood, A. K.; Brotherson, J. D. Microenvironment and nest site selection by ring-necked pheasants in Utah. Great Basin Naturalist 41(4): 457-460; 1981.

In: Tiedemann, Arthur R.; McArthur, E. Durant; Stutz, Howard C.; Stevens, Richard; Johnson, Kendall L., compilers. Proceedings--symposium on the biology of Atriplex and related chenopods; 1983 May 2-6; Provo, UT. General Technical Report INT-172. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 309 p.

POTENTIAL OF <u>ATRIPLEX</u> AND OTHER CHENOPOD SHRUBS FOR INCREASING RANGE PRODUCTIVITY AND FALL AND WINTER GRAZING USE

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ABSTRACT: There has been an increasing awareness of the value of shrubs in forage production and for revegetation of disturbed lands. Forage value is probably highest during fall and winter periods in cold desert ecosystems. Several Chenopodiaceae species have been analyzed for browse productivity and nutritive quality for livestock use. <u>Atriplex canescens</u> (Pursh) Nutt., <u>Kochia prostrate</u> (L.) Schrad., and <u>Ceratoides lanata</u> (Pursh) J.T. Howell, are highly productive and nutritious in mixes with <u>Agropyron</u> desertorum (Fisch.) Schult. These shrubs can significantly improve crude protein content and in vitro dry matter digestibility of sheep forage in the fall and early winter.

INTRODUCTION

Shrubs are a neglected resource for forage production in many parts of the world. Misconceptions of their value have hindered objective appraisals of shrubs. Shrubs are often considered weedy invaders, unpalatable to livestock, and low in feed value (McKell 1975).

Recently, shrubs have received increased interest as livestock forage and valuable revegetation species on disturbed lands, especially in arid regions. Their potential is being evaluated in many parts of the world, including the United States, Africa, Australia, and the Middle East. Several shrub species have been analyzed for productivity, chemical composition, palatability, and preference by grazing animals (Wilson 1969; Le Houreou 1980). Selection of superior shrubs, planting them in favorable sites, and using appropriate management practices, could improve arid ranges for animal production. However, management and integration of shrubs into grazing systems requires considerably more information than is presently available. The purpose of this paper is to review some of the major features of three chenopod shrubs in relation to their value for improving rangeland productvity and utilization.

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SHRUBS ON SEEDED RANGELANDS

Several thousand hectares of rangelands in the Intermountain region were planted to crested wheatgrass (<u>Agropyrcn desertorum</u> [Fisch.] Schult.) and <u>Agropyron cristatum</u> (L.) Gaertn.) in the 1940's and 50's. However, little attention was given to seeding forbs and shrubs. These monospecific seedings are used to provide grazing for livestock during the spring, summer, and fall (Frischknecht 1968). Some seeded foothill ranges are also used in late fall and early winter by livestock with or without supplementation (Kearl and others 1971; Cook and Harris 1968).

After late summer, most cool season grasses become dormant and their protein content declines below livestock condition maintenance needs while livestock protein needs remain high. Cook and Harris (1968) reported that mature grass forage is too low in protein to meet livestock gestation requirements. However, during this same time shrubs are high in protein, but are decidedly low in energy sources. Among the many shrubs found around the world, the family Chenopodiaceae has many genera adapted to arid and saline regions. Some of the genera with forage potential are: <u>Atriplex</u>, <u>Kochia</u>, and <u>Ceratoides</u>.

Fourwing Saltbush

Fourwing saltbush, (<u>Atriplex canescens</u> [Pursh.], Nutt.) a dioecious shrub, occurs widely on desert and foothill ranges in the Western United States. In Utah it produces abundant and nutritious forage as well as seeds. Fourwing saltbush is very drought resistant, survives and grows well on dry sites, and tolerates considerable alkalinity (Plummer and others 1966; Blauer and others 1975). According to Sampson and Jesperson (1963), fourwing saltbush rated good to fair as a browse for sheep, goats, and deer, and fair to poor for cattle and horses. Fourwing saltbush is easily established from seeds and cuttings and plants persist well in association with other shrubs and grasses. Monsen (1980) reported successful interseeding of fourwing saltbush and crested wheatgrass onto southern Idaho rangelands dominated by sagebrush.

Prostrate Kochia

Prostrate kochia (<u>Kochia prostrata</u> [L.] Shrad.) was introduced into the United States from Asia. It is a valuable shrub for browse in the USSR where it is utilized by both domestic livestock and wildlife (Shishkin 1936). Prostrate kochia is well adapted to dry western ranges and does well on neutral, saline, and even alkaline soils

(McArthur and others 1974). Productivity for this small chenopod is high according to Plummer and others (1970) who reported 1584 lb/acre (1,800 ka/ha) of dried herbage the year it was introduced to Utah. Balyan (1972) reported yields of 27.3 - 31.8 tons/acre (30-35 tons/ha) in pure stands in Russia.

Prostrate kochia belongs in the family Chenopodiaceae where some species, such as Halogeton glomeratus C.A. Mey, are known to cause oxalate poisoning in livestock (James and others 1967). In a study of forage quality, Davis (1979) indicated that oxalate levels in Kochia are lower than in fourwing saltbush and winterfat (table 1).

The tannin level (table 1) in prostrate kochia as well as in fourwing saltbush and winterfat is well below the critical level of 15 mg/g for livestock (Donnelly and Anthony 1969). The crude protein content of prostrate kochia (8.9-14.7 percent) is similar to that of fourwing saltbush (11.4-13.6 percent) and winterfat (10.1-16.8 percent) from August to March (Davis 1979).

Winterfat

Winterfat (Ceratoides lanata [Pursh.]J.T. Howell) is a subshrub that shows wide variations in stature. Dwarf forms may be less than 12 inches (30 cm) in height; robust forms grow up to 30 inches (75 cm). Winterfat is highly nutritious and palatable winter browse for livestock and big game. It is completely grazable except for the woody base and larger stems (Stevens and others 1977). As a result, even though it is relatively tolerant to grazing use, overgrazing has greatly reduced and even eliminated winterfat on some areas of the Intermountain region (Blauer and others 1975). Winterfat is potentially one of the most useful shrubs for range improvement and forage production on alkaline soils of the desert ranges in Utah and adjourning states where annual precipitation is less than 10 inches (25 cm).

Available literature on chenopods such as fourwing saltbush, prostrate kochia, and winterfat suggests that these shrubs exhibit considerable promise as natural supplements to crested wheatgrass for fall-winter grazing. Planting these shrubs in existing grass pastures could increase the use of mature grass forage that would otherwise not be grazed.

BIOMASS PRODUCTION

Chenopod shrubs on most arid lands throughout the world produce considerable amounts of biomass. Atriplex species grown under minimal cultural treatments can produce large amounts of forage. A study in Riverside, Calif. in 1969 showed that Atriplex polycarpa[Torr.] S. Wats., A. lentiformis [Torr.] S. Wats and A. canescens under minimal agronomic management could produce from 6679 to 8949 lb/acre (7 590 to 10 169 kg/ha) of herbage from closely spaced plants (Goodin and McKell 1971). Yields for fourwing saltbush ranged from 5195 to 5379 lb/acre (5 903 to 6 113 kg/ha) from low to high irrigation and compared favorably to alfalfa yields which were 5063 to 5861 lb/acre (5 753 to 6 660 kg/ha) (Goodin 1979).

In a seed pasture, fourwing saltbush produced 1.3 lbs (472 g) per plant at the Nephi Dryland Experiment Station in central Utah (Otsyina and others 1982). Atriplex size and productivity, however, depend greatly on both genetic and environmental factors. Recent studies at the USDA Forest Service Shrub Sciences Laboratory in Utah indicate that diploid Atriplex genotypes are more productive than tetraploid genotypes . Large differences among Atriplex ecotypes were shown in a study at the Nephi Station where ecotypes collected from nine different sites in the Intermountain region were grown in a uniform garden for 4 years under minimum cultural management (Van Epps and others 1982). Atriplex productivity averaged 8634 lb/acre (9 811 kg/ha), but highly significant differences existed among ecotypes.

The shrub biomass available for grazing is often difficult to estimate because the palatable new growth is protected by stout stems within the dense, compact growth form. Observations of sheep grazing on shrub species indicate that about two-thirds of the total current year's biomass is available as browse (Otsyina 1983).

Table 1.--Crude protein, crude fiber, tannins, oxalate, and carotene content of Kochia prostrata, Atriplex canescens, and Ceratoides lanata in November (Davis 1979).

Species	Crude protein	Crude fiber	Tannins	Oxalates	Carotene
	Percent	Percent	mg/g	Percent	mg/100g
K. prostrata	9.2	33.6	5.7	1.4	16.7
A. canescens	10.4	22.6	5.8	1.9	31.1
C. lanata	10.4	29.0	6.9	1.7	24.1

Productivity data for prostrate kochia are very scarce. Small pasture studies at the Nephi Station with prostrate kochia in combination with crested wheatgrass and other shrubs show that it is highly productive, 914 lb/acre (1 040 kg/ha) in a mix with crested wheatgrass. It contributed over 35 percent of the total available browse in the mixed pastures.

COMPETITION AND PERSISTENCE

Highest benefits from shrubs probably could be realized in mixtures with mature grasses. To contribute effectively, shrubs must be able to compete well with the grasses without detrimental effects on either component. Recent studies indicate that some chenopods are highly competitive in mixed stands. Rumbaugh and others (1982) examined forage quality and quantity in a pasture planted with various combinations of fourwing saltbush, grass, and legumes. They reported significant increases in forage yield when crested wheatgrass was grown with fourwing saltbush or legumes (*Astragalus cicer* L., *Astragalus falcatus* Lam. and *Medicago sativa* L.). The shrub and legume species not only contributed to an increase in production, but also stimulated the growth of crested wheatgrass. Less optimistic observations were reported by Monsen (1980) who noted that the presence of saltbush did not reduce grass density or herbage yields in Idaho.

Rumbaugh and others (1982) hypothesized that the increased forage yield in the grass/shrub mixtures may be attributed to nitrogen and mineral accumulation under the shrubs. Such a pattern was reported by Fairchild and Brotherson (1980) who found greater mineral concentrations under fourwing saltbush than under five other shrub species. Similarly, Charley (1977) and Charley and West (1975) detected a decline in nitrogen concentration with increasing distance from the shrubs. The mechanism of interaction between fourwing saltbush and crested wheatgrass is not well understood and may be unique to this combination since other workers (Rittenhouse and Sneva 1976) have reported a negative correlation between Wyoming big sagebrush (*Artemisia tridentata* Nutt. var. *wyomingensis*) crown cover and yield of crested wheatgrass.

Chenopod response to grazing and clipping has not been widely investigated, although there are indications that some chenopods are very tolerant to grazing even in mixes and grasses. Rumbaugh and others (1982) reported that regrowth following grazing on fourwing saltbush and crested wheatgrass was greater when grown in a mix than when grown alone. Prostrate kochia grown at the Nephi Dryland Field Station increased in both production and vigor when plants were grown with crested wheatgrass.

NUTRITIONAL VALUES

Protein

Protein is one of the most important nutrients in livestock diet. Serious problems may result when animals fail to obtain sufficient protein to maintain body weight. Ruminant animals require about 7 percent protein in their diets for the rumen micro-organisms to effectively digest and metabolize carbohydrates and fats (Fonnesbeck and others 1975). At protein levels below this amount, rumen function becomes severely impaired (Dietz 1972).

Shrubs contain higher levels of crude protein than grasses and forbs during fall and winter periods, but lesser amounts during spring and summer. Shrubs maintain a consistently higher protein content farther into the dormant season than do grasses. Cook and Harris (1968) reported a 75 percent loss of protein in grasses from early growth to seed formation while shrub species declined only 40 percent during the same period. Chatterton and others (1971) reported crude protein levels in *Atriplex polycarpa* ranging from 10 to 13 percent, although these amounts varied according to season. Among 43 accessions of *Atriplex canescens*, crude protein ranged from 5.3 to 17.1 percent during the winter period according to Welch and Monsen (1981), who attributed these differences to genetic variability.

Sheep will include significant amounts of chenopod shrubs in their diet when they are readily available during fall and winter periods. In a grazing study at the Nephi Field Station, Otsyina (1983) found that the protein content of shrub/grass forage selected by sheep was higher than grass forage. Protein content ranged from 5.12 to 8.9 percent in diets selected from a crested wheatgrass pasture, and 5.8 to 10.1 percent in a mixed shrub/grass pasture containing fourwing saltbush, winterfat, prostrate kochia, big sagebrush, rabbitbrush and bitterbrush.

Digestibility

Digestibility is important in determining the nutritive value of forages. The amount and composition of nutrients made available to grazing animals depends largely on the degree of digestibility of the particular forage. Digestibility depends greatly on the animal species, phenological stage of the plants, leaf/stem ratios, plant species, and to some extent, on secondary compounds in the plants that may inhibit microbial activity in the rumen (Cook and Harris 1968; Burzlaff 1971).

During the fall when both grasses and shrubs are mature, lignin content may reduce digestibility. Short and others (1973) reported a change from 68.2 to 50.2 percent in grass digestibility from May to November. Browse (twig) digestibility decreased from 86 to 36 percent from April to August while lignin content increased 60 percent.

At present, only limited information exists on seasonal browse digestibility by livestock. In October/November, in vitro dry matter digestibility levels observed in clippings were 52.2 percent for winterfat, 51.7 percent for prostrate kochia, and 47.8 percent for fourwing saltbush. At the same time, mature crested wheatgrass and fall regrowth of crested wheatgrass were 53.2 and 77.8 percent digestible, respectively (Otsyina 1983).

Diets selected by sheep on mixed shrub/grass pastures were more digestible than those selected from pure grass pastures in the fall (Otsyina 1983). In vitro dry matter digestibility of diets from pure grass pastures average 44.6 percent while digestibilities of diet materials from fourwing and mixed shrub pastures were 55.5 and 54.6 percent, respectively. The higher digestibilities of materials from the shrub pastures were attributed to increased protein content provided by the shrub component.

CONCLUSION AND RECOMMENDATIONS

Considering the existing data on chenopod shrubs, it is apparent that they have not been effectively utilized. Chenopods such as *Atriplex*, *Ceratoides*, and *Kochia* have great potential for improving the nutritive value of forage during the fall-winter grazing season in cold desert rangeland. Because of their favorable nutritive contribution, chenopod shrub species could be seeded in mixes with grasses as natural protein supplements to improve the nutritional value of forage for fall and early winter grazing.

Research on shrub biology and ecology should be intensified. Additional research on the nutritional value of shrubs and their management for sustained forage production under various grazing management systems is also recommended.

PUBLICATIONS CITED

Balyan, G.A. Prostrate summer cypress and its culture in Kirchizii. Cairo, Egypt: Faculty of Agriculture, University of Suez. 1972. 296 p. Translated from Russian by Saiid Salama.

Blauer, A.C.; Plummer, A.P.; McArthur, E.D.; Stevens, R; Guinta, B.L. Characteristics and Hybridization of some important intermountain shrubs. II. Chenopod family. Res. Paper INT-169. Ogden, UT; U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1975. 36 p.

Burzlaff, D.F. Seasonal variations of in vitro dry matter digestibility of three sandhill grasses. J. Range Manage. 24: 60-63; 1971.

Charley, J.L. Mineral cycling in range ecosystems. In: Sosebee, R.E., ed. Rangeland plant physiology. Range Sci. Series 4. Denver CO: Society for Range Management; 1977: 216-256.

Charley, J.L.; West, N.E. Plant-induced soil chemical patterns in Utah. J. Ecol. 63: 945-964; 1975.

Chatterson, N.J.;Goodin, J.R.; McKell, C.M.; Parker, R.V.; Rible, J.M. Monthly variation in the chemical composition of desert saltbush. J. Range Manage. 24: 55-56; 1971.

Cook, C.W. Comparative nutritive value of forbs. grasses and shrubs. In: McKell, C.M.; Blaisdell, J.P.; Goodin, J.R. (eds) Wildland shrubs--their biology and utilization. Gen. Tech. Rep. INT-1. Ogden, UT:U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1972: 303-303-310.

Cook, C.W.; Harris, L.E. Nutritive values of seasonal ranges. Logan, UT: Utah State University, Utah Agricultural Experiment Station; Bull. 472 1968. 55 p.

Davis, A.M. Forage quality of prostrate kochia compared with three browse species. Agron J. 71(5): 822-825; 1979.

Dietz, D.R. Nutritive value of shrubs, In: McKell, C.M.; Blaisdell, J.P.; Goodin, J.R. (eds.) Wildland shrubs--their biology and utilization. Tech. Rep. INT-1. Ogden, UT: U.S. Department of Agriculture, Forest Service Intermountain Forest and Range Experiment Station; 1972: 289-302.

Donnelly, E.D.; Anthony, W.B. Relationship to tannin, drymatter, digestibility and crude protein in *Services lespedeza*. Crop Sci. 9: 361-363; 1969.

Fairchild, J.A.; Brotherson, J.D. Microhabitat relationships of six major shrubs in Navajo National Monument Arizona. J. Range Manage. 33: 150-156; 1980.

Fonnesbeck, P.V.; Kearl, L.C.; Harris, L.E. Feed grade biuret as a protein replacement for ruminants. J. Animal Sci. 40(6): 1150-1184; 1975.

Frischknecht, N.C. Grazing intensities and systems on crested wheatgrass in Central Utah: Response of vegetation and cattle. Tech. Bull. 1388. Washington, D.C.: U.S. Department of Agriculture, Forest Service; 1968, 47 p.

Goodin, J.R. The forage potential of *Atriplex canescens*. In: Goodin, J.R.; Northington, D. (eds.) Arid Land Plant Resources Lubbock, TX. Texas Tech University Press. 1979, 418-424.

Goodin, J.R.; McKell, C.M. Shrub productivity - a reappraisal of arid lands. McGuinnies, W.A. Goldman, B.L.; Paylore, P. (eds.) Food fiber and arid lands. Tuscon, AZ: University of Arizona Press; 1971: 235-245.

James, L.F.; Street, J.C.; Butcher,J.E.; Shupe, J.L. The effects of Halogenton glomeratus, an oxalate producing plant, on rumen pH. J. Vet. Res. 29: 915-916, 1967.

Jones, R. The biology of Atriplex. Canberra, Australia: Division of Plant Industry, CSIRO; 1970. 128 p.

Kearl, L.C.; Frischknecht, N.C.; Harris, L.E. Wheatgrass, native grass and forest grazed by cattle. In: Proceedings, Western Section of American Society Animal Science. 1971. 22 p.

LeHouerou, H.M. Browse in North Africa. In: Proceedings International Symposium on browse in Africa; 1980 April 8-12; Addis Ababa Ethiopia. Addis Ababa, International Livestock Centre for Africa. 1980. 491 p.

McArthur, E.D.; Guinta, B.C.; Plummer, A.P. Shrubs for restoration of depleted ranges and disturbed areas. Utah Sci. 35: 28-33; 1974.

McKell, C.M. Shrubs--a neglected resource of arid lands. Science. 187: 803-809; 1975.

Monsen, S.G. Interseeding fourwing saltbush with crested wheatgrass on southern Idaho rangelands. In: Abstracts Society for Range Management, 33rd annual meeting, 1980 Feb. 11-14; San Diego, CA. 51 p.

Otsyina, R.; McKell, C.M.; Van Epps, G. Use of range shrubs to meet nutrient requirements of sheep grazing on crested wheatgrass during fall and early winter. J. Range Management. 35: 751-753; 1982.

Plummer, A.P.; Christensen, D.R.; Stevens, R: Hancock, N.V. Improvements of forage and habitat for game. Paper presented at 5th Annual Conference Western Association of State Fish and Game Commissioners, 1970, July 15. Portland, OR. Published by Utah Department of Fish and Game, Salt Lake City, UT.

Rittenhouse, L.R.; Sneva, F.A. Expressing the competitive relationship between Wyoming big sagebrush and crested wheatgrass. J. Range Manage. 29: 326-327; 1976.

Rumbaugh, M.D.; Johnson, D.A.; Van Epps,. G.A. Forage, yield, and quality in a great basin shrub and legume experiment. J. Range Manage. 35(5): 604-609; 1982.

Sampson, A.W.; Jesperson, B.S. California range brushlands and browse plants. Manual 33. Berkeley, CA; California Agricultural Experiment Station; 1963. 162 p.

Shiskin, B.K. (ed.) Flora of the USSR. Vol. 6. Centrospermae. 129 telstud Akademie Nauk. Transl. Jerusalem, Israel: Israel Program for Scientific Translation 6: 100-101; 1970.

Short, H.C.; Blair, R.M.; Eppe, E.A. Jr. Estimated digestibility of some southern browse tissues. J. Anim. Sci. 36(4): 792-796; 1973.

Stevens, Richard; Guinta, B.C.; Jorgensen, L.R.; Plummer, A.P. Winterfat. Publ. 77-2. Salt Lake City, UT: Utah Division of Wildlife Resources, 1977. 41 p.

Van Epps, G.A.; Barker, J.R.; McKell, C.M. Energy biomass from large rangeland shrubs of the Intermountain United States. J. Range. Manage. 35: 22-25; 1982.

Welch, B.C.; Monsen, S.B. Winter crude protein among accessions of fourwing saltbush grown in a uniform garden. Great Basin Naturalist. 41(3): 343-346; 1981.

Wilson, A.D. A review of browse in the nutrition of grazing animals. J. Range Manage. 22:23-27; 1969.

In: Tiedemann, Arthur R.; McArthur, E. Durant; Stutz, Howard C.; Stevens, Richard; Johnson, Kendall L., compilers. Proceedings--symposium on the biology of Atriplex and related chenopods; 1983 May 2-6; Provo, UT. General Technical Report INT-172. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 309 p.

DISTRIBUTION AND IMPORTANCE OF THE ATRIPLEX CASE-BEARING MOTH, COLEOPHORA ATRIPLICIVORA COCKEREL, ON SOME CHENOPOD SHRUBS, ESPECIALLY ATRIPLEX CANESCENS (PURSH) NUTT.

T. Blaine Moore and Richard Stevens

ABSTRACT: The *Atriplex* case-bearing moth (*Coleophora atriplicivora* Cockerel) appears to be a major cause of reduced seed production and foliage destruction of fourwing saltbush (*Atriplex canescens* [Pursh] Nutt.) on open ranges and in seed orchards. Livestock and big game grazing and predation seem to control the moth in natural populations of fourwing saltbush. In seed orchards, good control can be achieved by proper use of the insecticide malathion. Life cycle of the case-bearing moth is described.

INTRODUCTION

After several observations of insect damage to foliage leaves and seed production of fourwing saltbush (*Atriplex canescens* [Pursh] Nutt.) at Snow Field Station, Ephraim, Utah, steps were taken to determine the causative organism. The primary damage appeared to be done by a case-bearing moth identified as *Coleophora atriplicivora* Cockerell[1] (Coleophora Coleophoridae) (fig. 1).

Figure 1.--Adult Atriplex case-bearing moth.

Moths were first observed and collected by the authors from fourwing saltbush at the Snow Field Station in 1978. Plants showed extensive leaf damage, with some being completely defoliated. The larvae of the insects in question worked either side of the leaf, making an entrance hold and feeding on the leaf parenchyma and epidermal layers (fig. 2).

Figure 2.--Damage done to leaves of fourwing saltbush by Atriplex case-bearing moth larvae.

Although the damaged leaves were easy to identify, the insect was difficult to detect. The larvae doing the damage were eventually found to be in cigar-shaped cases 11.0 to 15.0 mm long and 2.5 to 4.0 mm wide (fig. 3).

More than 100 species of case-bearing moths (family Coleophoridae) occur in North America. During the first larval instar the moths are leaf miners, after which they move to the outside of the leaf, constructing a portable case in which they live throughout their larval and pupal stage. The cases are closed at the distal end and eventually become a cocoon for the pupae. Larvae inside the cases eat into the leaf, making circular mines, reaching in as far as they can to feed without leaving the case.

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[1]Heppner, J. Smithsonian Institution, Washington, D.C. Specimens identified for authors in August 1979, and are in Snow College collection.

Cases are constructed from parts of the plant upon which the larvae feed, and are lined with silk. The insects winter as partly grown larvae in cases which are fastened securely to a twig or branch with silk (Baker 1972).

Figure 3.--Cigar-shape (arrow) of the Atriplex case-bearing moth (2d instar) attached to a leaf of fourwing saltbush.

Most species of the family Coleophoridae belong to the genus Coleophora, of which 10 species infest numerous eastern deciduous trees (Baker 1972). Only one species, C. laricella (Hubner), is of importance in western forests, infesting western larch (Larix occidentalis Nutt.) (Furniss and Carolin 1977).

California case-bearers (C. sacramenta [Heinrich]), have been found to infect willow (Salix sp. L.), almond (Prunus amygdalus Batsch.), and apricot (Prunus armeniaca L.). Infestations on apple, cherry, peach, plum, and pear have also been reported (Essig 1948). The need for control is obvious when complete defoliation is caused by these insects.

The only reference to C. atriplicivora known by the authors and Davis[2] is by T. D. A. Cockerell (1898). His reference describes the adult only, with brief mention of his inability, except in rare instances, to raise adults from larvae.

Description (Adapted from Cockerell 1898)

The adult Atriplex case-bearer (fig. 1) is from 10 to 20 mm long. The head, thorax, and primaries (forewings) are white with a delicate ochreous tint. Secondaries (hindwings), abdomen, legs, and underparts of the body are silvery-white; hind tibiae are pale ochreous, clothed with long white hair. Fringes are pale, faintly greyish, tinged with ochreous. The longest fringe on primaries is longer than the greatest diameter of the wing. Primaries are superficially without streaks, but close examination shows that the courses of the veins are broadly ochreous-tinged, while the intervals are narrowly white, producing an obscure longitudinal streaking. This is somehow intensified with the intervals being peppered with minute dark grey specks. Palpi are quite long (1.5 mm), the penultimate segment with a well-marked terminal brush of scales. Antennae are delicately annulated with white and pale grey, the basal two-fifths heavily clothed so as to appear considerably thickened. Abdominal segments 2 to 6 (all specimens examined by the authors had 6), each with a pair of longitudinally narrow brown (i.e. scaleless) marks, one on each side of the median line.

METHODS

Extensive observations were made in 1980 and 1981 at Snow Field Station and in native populations of fourwing saltbush throughout Utah, northern Arizona, and southern Nevada for the presence of the Atriplex case-bearing moth. Fourwing saltbush populations were regularly examined during the months of June and July at Bald Mountain, Chester, and Palisade State Park, all in Sanpete County, and Marysvale (Piute County). Collections and observations were made at St. George (Washington County), at the mouth of Spanish Fork Canyon (Utah County), near Grantsville (Tooele County), near Pipe Springs Arizona, and near Bunkerville, Nevada. Observations were also made to determine if the moth occurred on other chenopods.

Five years (1978 through 1982) of field observations and laboratory rearings made it possible to determine and confirm the life cycle of the Atriplex case-bearing moth.

A quantitative study was begun in 1981 to determine number of moths and exact damage to seed production on fourwing saltbush at the Snow Field Station. Twelve female plants each from two populations of related fourwing saltbush were selected. Eight branches 6 to 8 inches (15 to 20 cm) long were marked two on each of the south, east, north, and west sides of each plant. Branches were located 18 to 24 inches (45 to 60 cm) above the ground. One population was sprayed with the insecticide malathion in early June and mid-June to kill larvae that have overwintered and were moving onto foliage and again in mid-August to kill larvae of the new generation. Malathion was applied at the rate of 5 pounds of active ingredients per acre (5.6 kg/ha). Application was made with a ground rig. Fourwing saltbush plants were sprayed until the spray was dripping from the leaves. The total number of larvae present on each of the marked branches was counted on June 4 (4th instar), June 16 (5th instar), July 10 (pupae), July 28 (2d instar larvae of 2d generation).

Ten plants each from the sprayed and nonsprayed populations were selected at random. Seeds from each plant were collected, cleaned, and weighed. Seed productions were compared by a "t" test (Woolfe 1969).

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[2]Davis, D. S. Smithsonian Institution, Washington, D.C. Personal communications; 1982.

RESULTS

Distribution

The Atriplex case-bearer was found on several species of the plant family Chenopodiaceae. By far the largest number were found in cultivated stands of fourwing saltbush. Specimens were observed in widely scattered native stands from Washington County in southwestern Utah to Tooele County in northwestern Utah.

Cases were also observed on A. lentiformis (Torr.) Wats., A. tridentata Kuntze, A. confertifolia (Torr & Frem.) S. Wats., Sarcobatus vermiculatus (Hook.) Torr., and Halogeton glomeratus (C.A.) Mey. in Ledeb. Of these, A. tridentata had the greatest infestation. A. confertifolia in most areas had only a few, and only two cases each were observed on H. glomeratus and S. vermiculatus. Those on A. tridentata and A. confertifolia were hatched out in the laboratory and proven to be the same species as occurs on A. canescens.

A similar case-bearer was found on rubber rabbitbrush (Chrysothamnus nauseosus [Pall.] Britt. var. graveolens [Nutt.] Piper). The cases were more than 15.0 mm long, were somewhat more slender than those of the Atriplex case-bearer (2 to 2.5 mm wide), and were devoid of any debris characteristically found on C. atriplicivora. Species identification was not made for the rabbitbrush case-bearer.

Life Cycle

The adult Atriplex case-bearers begin pairing up in late June and remain in the mating position (genitalia connected and heads pointed in opposite directions) for 2 or 3 days (fig. 4-1). Eggs, about 0.17 mm in diameter, sculptured and light amber in color, are deposited, one per leaf, on the smooth surface of the leaf Atriplex, or in some other feature which would give protection (fig. 4-2). Within one week the eggs hatch, and the first instar larvae (fig. 4-3) burrow from their shells directly into the leaf, becoming mining insects. They remain as leaf-mining larvae throughout this first instar. These insects then change their eating habits as they become too large to remain leaf miners. The larvae emerge from the leaf through emergence holes and begin to spin cigar-shaped cases. There is only one larva in each case. The larvae will feed for a time on the leaf (fig. 4-4), then move to a place on the larger branches of the fourwing saltbush (fig. 4-5). Here they go into diapause sometime before cold weather (September or early October). Diapause is probably triggered by photoperiod, although other factors might also be involved, such as lower nighttime temperatures, slowing up of plant growth, and possibly the production of insect-inhibiting chemicals (Maugh 1982).

As soon as new leaves begin to appear on fourwing saltbush, the second instar larvae of the case-bearer release their hold on the stem and move up from the large basal branches of the plant and begin to feed. They seem to feed on the young opening leaves and flower buds, then later move to the larger leaves of the plants. They eat into a leaf from either surface and, while remaining in the case, begin to feed on the parenchyma and epidermal tissues of the leaf. By reaching into the entrance hole of the leaf, they extend themselves as far as they can go without leaving their cases. They make circular excavations in the leaf, with entrance

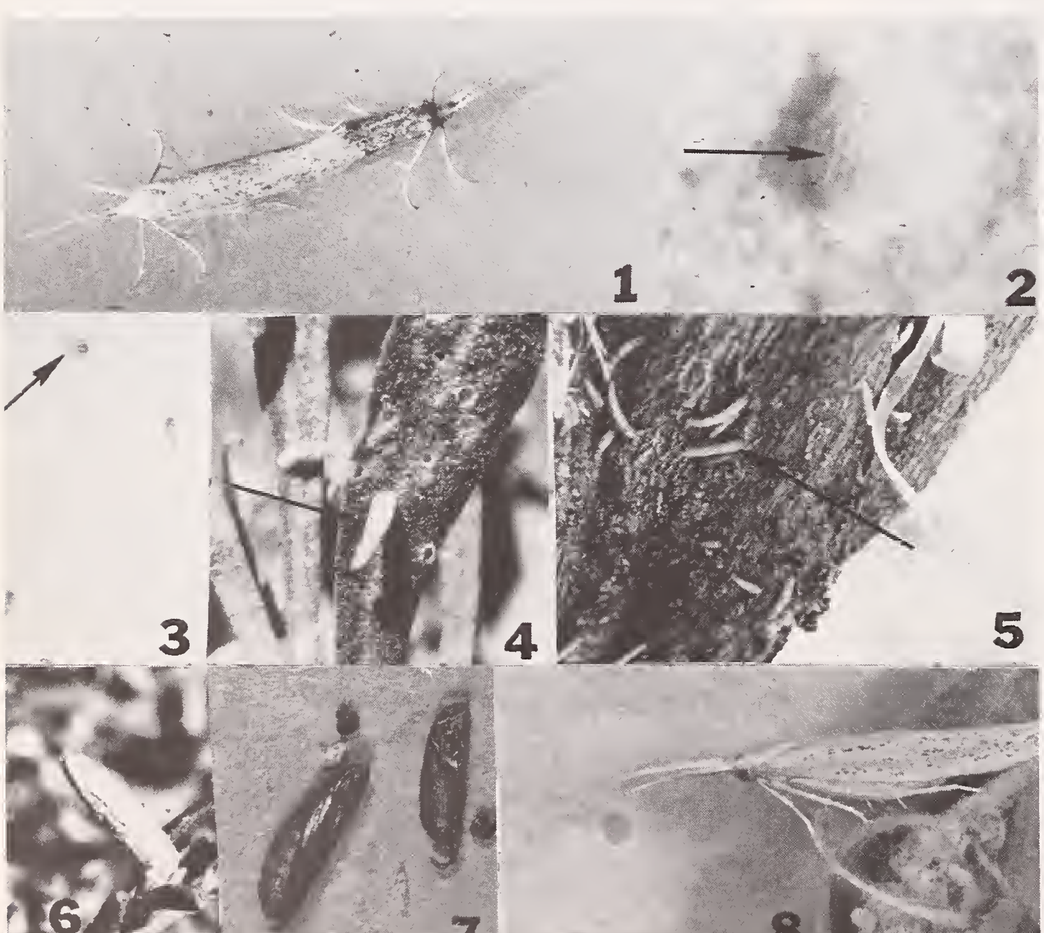

Figure 4.--Coleophora atriplicivora life cycle: (1) male (right) and female (left) moths mating (late June), (2) egg on lower surface of leaf of Atriplex canescens, (3) 1st instar larva (mid-July), (4) 2d instar larva feeding on leaf (late July), (5) 2d instar larva in diapause (September-May), (6) 4th instar larva in case (middle of June), (7) pupa removed from cases (late June), (8) adult moth (early July).

Figure 5.--Leaves of fourwing saltbush completely destroyed by the activities of Atriplex case-bearing moth larvae.

Figure 6.--Case (arrow) of an Atriplex case-bearing moth disguised with floral parts among the male flowers of fourwing saltbush.

holes roughly in their centers. When they cannot reach any additional food, they move to a new location, make a new entrance hole and excavate. This process is repeated many times until the leaf is destroyed (fig. 5).

By using the silk they produce, along with the plant debris, these larvae build new cases, at each of the earlier moults, to compensate for their increase in size, with possible exceptions of the moults between the fourth and fifth instar. Positive evidence of cases at this stage was not obtained (fig. 4-6 shows 4th instar larva in case).

The larval case spun by the larva is silk. Movement of larvae on the plant causes considerable material to adhere to the outside of the case. This plant material frequently consists of flower parts which break up the smooth outline of the case. This is a good example of protective adaptation for the insect (fig. 6), and is especially apparent on male plants.

The cases on female plants, which pick up some materials, are more readily seen on the green leaf or in the inflorescence. Because cases on female plants are easily detected, they may fall prey to predators, hence are fewer in number.

The larvae upon completing their last instar, move to places on the stems where several small branches arise from a node (fig. 7). It is here that pupation occurs; the larval case now becomes the pupal case (fig. 4-7, pupae removed from cases).

Figure 7.--Pupal case (arrow) of an Atriplex case-bearing moth after having migrated to the axil of branches of fourwing saltbush.

This case is 12 to 15 mm long and 2.5 to 4.0 mm wide at its greatest width. The adult moths appear from 1 week to 10 days after the beginning of pupation (fig. 4-8).

Moth Abundance and Its Effect On Seed Production

There was a change in the number of individuals at three points in the life cycle of the Atriplex case-bearing moth (table 1). The number of insects varied greatly between individual shrubs and between generations. However, insect numbers did not vary among the four sides (south, east, north, and west) of an individual shrub.

Table 1.--Number of insects on eight branches 6 to 8 inches (15 to 20 cm) long on each of 12 fourwing saltbush plants on June 4, June 16, July 10, and July 28.

Plant No.	June 4 4th instar	June 16 5th instar	July 10 pupae	July 28 2d instar generation
1	42	38	33	17
2	52	52	35	55
3	24	23	23	31
4	56	52	52	68
5	54	49	34	69
6	75	69	51	107
7	45	43	46	100
8	65	59	43	113
9	56	46	48	63
10	181	171	96	122
11	123	119	98	79
12	83	83	93	63
Avg. per plant	71	67	52	74

Seed production was highly significantly affected by the presence of the moth. Mean seed weight per sprayed plant (no moths) was 290 grams, compared to a mean seed production of only 2.5 grams for nonsprayed plants (table 2). In three native stands of fourwing saltbush, where infestation of the moth was found, seed production was near zero.

Grazing seemed to have an effect on moth density and seed production. Atriplex tridentata is found in the Sanpete Valley along roadways and in other nongrazed areas. In one such area there was a 5-acre field of trident saltbush next to the roadway. Along the roadway and fencelines the case-bearing moth was abundant and no seed production occurred. In the field where sheep pastured in the spring and autumn no cases could be found, and there was good seed production.

A number of native fourwing saltbush stands were studied. In those stands where grazing occurred (sheep, cattle, deer) few moths were found and seeds were produced. Evidently, many cases containing larvae are eaten by animals, especially during spring and summer grazing when the larvae are predominantly on the foliage.

Table 2.--Dewinged fourwing saltbush seed production (grams) on 10 sprayed (Malathion) and 10 nonsprayed plants.

Plant No.	Sprayed	Nonsprayed
1	368	5
2	260	0
3	100	6
4	164	0
5	300	0
6	336	10
7	244	0
8	632	4
9	204	0
10	300	0
Total	2,899	25
Avg. per plant	290	2.5

General Observations

Van Epps[3] found and reported to the authors that all the male plants of A. canescens on the Utah State University's Snow Field Station study area were severely damaged by C. atriplicivora. Fourwing saltbush plants on this study area were inspected. The female plants did not appear to be damaged to any great extent, however, no seed was produced. On close examination it was easier to find cases on female plants than on male plants. This was due to better camouflage for the cases in the male inflorescence (fig. 6). Additional observations were made at three range locations. In all instances more cases were observed on female plants than on male plants. One really had to look to find cases on the male plants. The cases on male plants that were found were among the inflorescences.

After looking for the cases, each bush was swept with a beating net. More larvae were found on the male plants than on the female. Because cases on female plants were more conspicuous, they could be more susceptible to predation. Birds could be major predators, though birds themselves were not observed actually taking the larvae. However, they were quite active in fourwing saltbush stands during early morning hours. The rock wren (Salphinctes obsoletus [Say]) and some sparrows (species unidentified) were frequent visitors to the plants. A clerid beetle (Hydnocera spp. Newn) was observed while moving along a branch of A. canescens with a case in its mandibles. Insects, however, are generally less important as predators than as parasites.

[3] Van Epps, G. A. Utah State Agricultural Experiment Station, Ephraim, Utah. Personal communication; 1982.

Of the more than 200 adult moths which were raised from larvae in the laboratory, none were found to have been parasitized. This is not to suggest that parasitism does not exist in this group, but simply on these occasions they were free of parasites. Adults were raised from the last instar larvae and from pupae gathered in the field, giving potential parasites ample opportunity to lay their eggs on them. Adults were raised in the laboratory during three successive summers with all hatching and no evidence of parasites.

CONCLUSION

The Atriplex case-bearing moth, C. atriplicivora was found to be abundant in cultivated monoculture seed orchards of fourwing saltbush, where it caused a great amount of foliage and seed damage. In natural populations of A. canescens, however, moth populations were not observed to be as great as in seed orchards. The moth was found on a number of other chenopods.

Feeding by browsing animals such as deer, cattle, and sheep seemed to play an important role in moth control. These animals feed on the plants during early spring and summer when the overwintering larvae are becoming active and are going through various stages of their life cycle on the leaves. In the fall these insects migrate to the stems to go into diapause. Very little natural predation was observed during the study. Some birds may take the larvae, and a clerid beetle was observed with a case in its mandibles.

No parasites were found associated with the more than 200 moths raised from larvae in the laboratory.

CONTROL OF ATRIPLEX CASE-BEARING MOTH

In central Utah seed orchards the Atriplex case-bearing moth can be successfully controlled by spraying the insecticide Malathion (5 pounds of active ingredients per acre [5.6 kg/ha]) in early June with followup spraying in mid-June moving up onto the foliage. An additional spraying should be done by mid-August to kill the new generation larvae. Plants sprayed with Malathion produced 100 times more seed than did plants not sprayed.

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PUBLICATIONS CITED

Baker, W. Eastern forest insects. Misc. Publ. 1175. Washington, DC: U.S. Department of Agriculture Forest Service; 1972. 404 p.

Cockerell, T. D. A. Two new case-bearing Lepidopters. Ann. Mag. Nat. 2(7): 403; 1898.

Essig, E. O. Insects of Western North America. The MacMillan Co., New York, NY; 1948. 745 p.

Furniss, R. L.; Carolin, V. M. Western forest insects. USDA Forest Service, Misc. Publ. 1339. Washington, DC: U.S. Government Printing Office; 1977. 654 p.

Maugh, T. H. Exploring plant resistance to insects. Science 216: 722-723; 1982.

Woolfe, C. M. Principles of biometry. Princeton, NJ: D. Van Nostrand and Company, Inc.; 1968. 359 p.

In: Tiedemann, Arthur R.; McArthur, E. Durant; Stutz, Howard C.; Stevens, Richard; Johnson, Kendall L., compilers. Proceedings--symposium on the biology of Atriplex and related chenopods; 1983 May 2-6; Provo, UT. General Technical Report INT-172. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 309 p.

STATUS OF INFORMATION CONCERNING INSECTS ASSOCIATED WITH SELECTED SPECIES OF *ATRIPLEX*

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ABSTRACT: The value, uses, needs, and limitations of a Utah State University collection of approximately 140 insect species associated with *Atriplex* spp. are discussed. Examples of families and species of insects collected, their guilds and general impacts on vegetation and reproduction of *Atriplex* species are presented. Needs are outlined for interdisciplinary research to: (a) assist seed analysts, (b) develop acceptable cultural, biological, or chemical management strategies to control insects, and (c) benefit those responsible for range improvements, management, and native plant enterprises.

INTRODUCTION

Entomologists at Utah State University (USU), Logan, Utah, have collected rangeland insects, including those from *Atriplex,* for approximately 60 years according to Knowlton (1932).

Until recently insects associated with *Atriplexes* had not been a priority for USU researchers because their major efforts have been collecting and identifying rangeland insects in general, but observers of rangelands report they have seen devastating impacts of mealybugs and root borers on large acreages of *Atriplex* for many years (Sharp 1983, personal communication.)[1]

Demands for native plant seeds, for containerized plants, and bareroot stock for land rehabilitation have given new importance and emphasis to studies of insects associated with forbs and shrubs.

Investigations of selected shrub and forb insects of major importance, their ecotypes, and the beneficial and injurious insects associated with them were expanded in 1979 when a five-year Ecosystems Reconstruction Project was formalized with USU and the National Science Foundation. In-depth studies of bitterbrush, *Purshia tridentata* (Pursh) DC., were initiated by USU in 1981.

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[1] Dr. Lee A. Sharp, Professor of Range Resources University of Idaho, Moscow, Idaho.

Taxonomic studies and general observations of insect injury to *Atriplex* species and their seed have been included in research to date at USU. The announcement of this *Atriplex* symposium has created an awareness that the *Atriplexes* merit a high research priority for entomologists and has resulted in a closer examination of *Atriplex* data now on hand.

Some data presented here come from the unique orchards established by Gordon Van Epps at Ephraim and Nephi, Utah. The orchards had been infested with insects and offered an opportunity for researchers at Snow College and USU to cooperate in studies of insects of *Atriplex* and several other rangeland plants grown as monocultures.

Dr. G. E. Bohart, an experienced insect taxonomist, has participated as an entomological consultant for a number of rangeland studies that included insects. His valuable collections have been incorporated in the USU range insect collection. Dr. Bohart has helped prepare data to show the present status of information concerning insects associated with several species of *Atriplex*.

The objective of this paper is to summarize some of the information available about the species of insects collected from *Atriplexes*, their relative abundance, known or suspected impacts on plants and seed, management principles, problems, and needs associated with producing, processing, and evaluating *Atriplex* seed.

The first essential step in diagnosing and solving problems with insects associated with *Atriplex* is correct identification of the insects. The list of insects collected from *Atriplexes* now includes 142 species and the list is increasing, but much remains to be done on the identification of these insects.

Little research has been done on biologies of most of the insects associated with *Atriplex* species, but inasmuch as the general behaviors and impacts of insect groups that have been studied on other host plants often are similar, helpful information can be extracted from the taxonomic data and field observations now on hand about *Atriplex* insects.

ATRIPLEX INSECT LITERATURE

Much information exists about many aspects of Atriplex bionomics: its wide distribution, ecotypes, physiology, adaptability, nutritional value, reproduction, and animal associations (Cristi 1971; McArthur and others 1978; Monsen 1975; Plummer and others 1966; Stevens and others 1981).

Knowlton (1932) lists the the following Atriplex species as plant hosts of the beet leafhopper Eutetix tenellus (Baker), a destructive pest of sugar beets and tomatoes: powelli S. Wats., canescens (Pursh) Nutt., argentes Nutt, confertifolia (T. and F.) S. Wats. patula hastata (L.), nuttalli falcata (Jones), nuttalli S. Wats., rosea L., and truncata (Torr.) A. Gray.

Some mimeographed reports found at USU are those such as that by Knowlton (1966), which lists insects he or others found injuring Atriplex and other rangeland plants.

US/IBP Desert Biome studies summarized by Sferra[2] (1974, 1975, unpublished data) lists insects found on Atriplex, and other range plants, but few reports of specific research or published papers concerning the detailed biologies or economic impacts of injurious or beneficial insects on Atriplexes have yet been located.

In 1983 a cooperative project between USU and the U.S. Department of Agriculture, Forest Service Intermountain Forest and Range Experimentation Shrub Laboratory at Provo, Utah, was initiated to collect a list of known insects associated with rangeland shrubs, including Atriplexes, and to review and cross-index all related literature that can be found.

There is a scarcity of information in the literature about insects associated with the Atriplexes. Furniss (1972) listed a number of insects collected from browse plants, but none is indicated for Atriplex. In a publication concerning important shrub insects, Furniss and Barr (1975) listed only one species from A. canescens. A range insect publication commissioned by the Society for Range Management (Hewett and others 1974) does not list any insects associated with A. canescens.

Watts and others (1982) pointed out that there is an absence of detailed biological and control technology literature on insects of browse plants and that emergency control of Orthezia scales on Atriplex spp. might be justified if methods were available.

[2]Sferra, P. R. Classification and quantification of invertebrate activity and the role of invertebrates in nitrogen processing in plants, litter and soil in Curlew Valley. US/IBP Desert Biome Res. Memo 74-28; Ecology Center, Utah State University, Logan, Utah; 1974. 8 pp. Same 1975. 6 pp. (unpublished)

Moore[3] (1983, unpublished data) reports studies of a case-bearing moth of A. canescens. A snout moth (Pyralidae) was reported to have killed A. confertifolia plants (Stoddard and others 1975). Vallentine (1971) indicated grasshoppers injured a higher proportion of fourwing saltbush seedlings than did rabbits.

Palmer (1952) recorded Xerophilaphis tetrapteralis (Cockerell), an aphid found on "Atriplex Saltbush."

A USU publication presents an introduction to rangeland insects (Haws and others 1982a).

INSECTS AND ATRIPLEX SPECIES

Present evidence from native and domestic Atriplex communities suggests that the kinds and densities of insects associated with different plant ecotypes vary considerably (Meadows 1983, unpublished data).[4]

Table 1 lists 107 insect species collected by sweeping Atriplex canescens (Pursh) Nutt. in orchards at Ephraim and Nephi, Utah, and shows the families categorized into guilds (insects that utilize the same resource the same way, e.g. feed on roots, gather pollen). Many records of genera and species are combined in this listing of insect families. Use of family identifications is of limited value in diagnosing and solving insect problems because so many different kinds of insects may be found within a family. Table 1 shows that some of the injurious or beneficial impacts of the immature forms and their adults may be different.

Having to distinguish the immature insects from their adults greatly increases taxonomic tasks and complicates the determination of insect impacts because their feeding patterns may be vastly different. (See table 1)

Table 2 demonstrates the kind of information concerning insect genera and species that is combined by families in table 1. Table 2 also shows why it is necessary to have insect collections from specific geographical regions. Note there is only one overlapping species collected in these two areas, the ant, Formica lasioides. It is necessary to collect insects regularly during the year, and perhaps for several years, using various collecting methods, to get accurate, complete samples of the insects present in an area.

[3]Moore, T. Blaine. Distribution and economic importance of the case-bearing moth, Coleophora atriplicivora, on some Chenopod shrubs, especially Atriplex canescens. Proceedings, this symposium.

[4]Meadows, Roy W. Graduate student, Department of Biology, Utah State University, Logan. Unpublished data.

Table 1.--Insects collected from Atriplex canescens in 200 sweeps near Ephraim and Nephi, Utah, on August 1, 1981, and September 7, 1981. Shown are order and family, number of insect species collected, and feeding habits (guilds) of adults and immatures for each family.

Order/Family	Number	Feeding habits of adults/immatures
Coleoptera	12	Variable feeding habit/same as adults
Coccinellidae	2	Aphid, mite predators/same as adults
Chrysomelidae	5	Leaf skeletonizers/same as adults
Melyridae	1	Aphid, mite, small larva predators/ predators of soft-bodied insects near plant crown
Meloidae	1	Chew leaf and flower tissue/some predators of bees, some in grasshopper egg masses
Mordellidae	1	Chew leaf tissue/same as adults
Staphylinidae	1	General predators/same as adults
Lathridiidae	1	Feed on fungi/same as adults
Hemiptera	13	Sap or blood feeders/same as adults
Pentatomidae	2	Most pierce leaves, reproductive parts, a few predators/same as adults
Lygaeidae	3	Pierce fruits, seeds, soft tissue, a few are predators/same as adults
Nabidae	1	Predators of aphids, immature mirids/same as adults
Reduviidae	1	Predators of other insects/same as adults
Miridae	3	Pierce leaf, bud, young tissue/same as adults
Anthocoridae	1	Predators of thrips, mites; sometimes pierce flower parts/same as adults
Tingidae	1	Pierce leaf epidermis/same as adults
Neididae	1	Pierce leaves and stems of herbaceous plants/same as adults
Homoptera	17	Sap feeders, many oviposit in plant tissue
Cicadellidae	14	Pierce leaf tissues/same as adults
Membracidae	1	Pierce leaf and stem tissues/same as adults
Delphacidae	1	Pierce leaf and stem tissues/same as adults
Psyllidae	1	Pierce leaf tissues/same as adults
Hymenoptera	44	Most feed on pollen and/or nectar, some omnivorous
Halictidae	4	Visit flowers, store pollen and nectar/eat pollen and nectar stored by adults
Sphecidae	5	Take nectar from flowers, store specific insects in nest/feed on insects stored by the adults
Eumenidae	1	Take floral nectar, store lepidopterous larvae/eat larvae stored by adults
Formicidae	3	Omnivorous--eat seeds, nectar, honeydew insects, etc./eat food supplied by the adults
Bethylidae	2	Take nectar, oviposit in beetle larvae "in situ"/consume beetle larvae from within
Dryinidae	1	Oviposit in leafhoppers/consume leafhoppers from within
Pteromalidae	5	Eat nectar and pollen, oviposit in host insects/consume host insects from within
Eulophidae	9	Eat nectar and pollen, oviposit in host insects/consume host insects from within
Encyrtidae	4	Eat nectar and pollen, oviposit in host insects/consume host insects from within
Eurytomidae	2	Some oviposit in host insects, some in seeds or stems/consume the oviposition medium
Chalcididae	2	Eat pollen and nectar, oviposit in host insects/consume host insects from within
Scelionidae	1	Oviposit in eggs or insects/consume the egg or host from within
Mymaridae	1	Oviposit in insect eggs/consume the host egg from within
Braconidae	4	Eat nectar and pollen, oviposit in insects or spiders/consume host from within

Table 1.--Continued.

Order/Family	Number	Feeding habits of adults/immatures
Diptera	16	Most species feed on nectar and/or pollen, animal excrement etc./various but usually feed inside food material
Tachinidae	2	Feed on nectar or pollen, oviposit in insects/consume host insects from within
Calliphoridae	1	Feed on floral products, exudates of decay/scavengers of decaying substances
Anthomyiidae	1	Most feed on nectar, other plant exudates/some are scavengers, some feed on bulbs, roots, some on old carrion
Tephritidae	1	Drink nectar, other plant exudates/some eat fruit, some induce plant galls, especially in heads of Compositae
Otitidae	2	Drink nectar, other plant exudates/mostly eat decaying plant materials
Milichiidae	1	Drink nectar, other plant exudates/saprophagous or copraphagous
Sepsidae	1	Drink nectar, other plant exudates/feed in excrement or decaying plant material
Chloropidae	3	Feed on plant or animal exudates/feed on roots or stems, some scavengers in plant material
Chamaemyiidae	1	Feed on plant exudates/some parasitic in scale insects
Bombyliidae	1	Feed on nectar, oviposit near or on host insects/most external parasites of bee or wasp larvae, grasshopper eggs
Stratiomyidae	1	Some feed on nectar, pollen/predaceous or scavengers under bark, in excrement, or other organic matter
Pipunculidae	1	Drink plant exudates, oviposit in leafhoppers/consume host insects from within
Lepidoptera	1	Drink nectar/consume plant tissue
Hesperiidae	1	Drink floral nectar/chew leaf material
Orthoptera	1	Chew leaves and stems of various plants
Acridiae	1	Chew leaves and stems/same as adults
Odonata	1	Predaceous or don't feed as adults/predaceous and aquatic as immatures
Coenagrionidae	1	Don't feed/predaceous in ponds, streams
Thysanoptera	2	Some rasp plant epidermis, some predators on other thrips/same as adults
Total species	107	

Table 2.--Data showing differences in the species and relative abundance of insects collected from *Atriplex canescens* (Pursh) Nutt. at two different dates and locations.

Bonanza, Utah, June 7, 1976, insects collected in 50 sweeps 12-inch net			Twin Falls, Idaho, Aug. 16, 1983, insects collected in 80 sweeps 12-inch net		
Order/Family	Genus & species	Number of individuals	Order/Family	Genus & species	Number of individuals
Hymenoptera (wasps, ants, etc.)			Hymenoptera		
Scelionidae	*Trissulens utahensis* Ashm.	2	Brachonidae	*Agathis gibbosa* (Say)	2
Eulophidae	eulopid #1[1]	4			
Formicidae	*Dorymyrmex pyramiscus* (Roger)	2	Formicidae		
	Formica lasioides Emery	3		*Formica lasioides* Emery	8
Diptera (flies, gnats, etc.)			Diptera		0
Chamaemyiidae	*Leucopis* #1	2			
Chloropidae	*Siphonella* #1	2			
	Philygria debilis Loew	2			
Coleoptera (beetles)			Coleoptera		
Bruchidae	bruchid #4	2	Chrysomelidae	*Monoxia elegans* Blake	232
		0	Melyridae	*Collops bipunctatus* Say	2
Lepidoptera (butterflies and moths)			Lepidoptera		
			Psychidae	psychid #1	3
Hemiptera (true bugs)			Hemiptera		
Pentatomidae	*Thyanta punctiventris* V.D.	7	Pentatomidae	*Chlorochroa sayi* Stal	2
Total		[2]13			249

[1]Numbers or letters identify unknown species that have been or will be sent to specialists for identification.

[2]Of 34 species only those 13 with more than one individual collected are shown.

Seven of the insects in table 2 are not identified to species. The unidentified specimens will have to be sent to taxonomic specialists for further identification.

Of 34 species collected at Bonanza, 13 (38 percent) are parasites or predators of other insects, and might be considered beneficial from the human viewpoint. Two species are considered "visitors" (not feeding or having any direct impacts or associations with fourwing saltbush). The remaining 19 species (59 percent) contained both chewing/rasping insects and sucking insects, generally considered to be injurious.

The size of the insects varied from about .32 inch (.75 mm) to more than 2 inches (50 mm) in length. Size or numbers of individuals are not always reliable criteria of the importance of an insect. For example, a population of minute egg parasites might almost completely destroy a generation of larger insects. A few small leafhoppers carrying viruses may infect an entire group of plants. Small seed chalcids may drastically reduce a plant's seed crop, but some migrating grasshoppers can destroy nearly all vegetation in their path.

The conclusions from this small collection cannot be extrapolated through a whole season or to other locations. The kinds and numbers of insects that can be collected vary considerably at different times of the day, under different conditions of temperature, sunlight or cloudiness, place to place, week to week, month to month and year to year.

Some insects hatch from eggs in the spring, develop in a few weeks, mature, and lay eggs that remain as eggs for more than nine months. Others overwinter as adults, pupae, or larvae, and some insects produce a new generation several times during a season. There are many combinations of these kinds of life and seasonal cycles.

Table 3 shows that in this particular sample a large portion of the insects collected are beneficial, that is, pollinators, parasites, or predators of other insects. In this sample there were a few more beneficial insects than harmful ones. Some of the insects were neutral in that they appear to neither injure nor benefit the plants. The proportion of injurious and beneficial insects shown in table 3 undoubtedly changes during the year and in different areas.

INSECTS AFFECTING *ATRIPLEX* SEED

Much of the commercial *Atriplex* seed that has been examined at USU was infested with or damaged by chewing or plant-sucking insects. Damage occurred as the seed developed or when it was in storage. Among approximately 300 samples of commercial seed examined, many samples contained living dermestid larvae that were eating the seed.

Seed chalcids are tiny wasp-like insects that inject eggs into the developing seed. The larvae that hatch from the eggs grow as the seed develops. The adults may be distributed when the seed is planted. Inasmuch as a seed containing an insect weighs almost the same as a noninfested seed, infested seeds are not always removed in the gravity cleaning process. Seeds containing chalcids may be planted with good seed. (See fig. 1)

Table 3.--Approximate status of 50 families[1] of adult (AD) and immature (IM) insects collected from *Atriplex canescens* (Pursh) Nutt. near Nephi and Ephraim, Utah, 1979.

I Beneficial		II Injurious		III Neutral[2]	
AD	IM	AD	IM	AD	IM
21	30	22	22	13	7

[1]Numbers do not total 50 because some insect species within the same family have different feeding and behavior patterns. There were more beneficial than injurious insects.

[2]Neutral=insects visit or rest on the plants, do not feed or lay eggs on them.

Figure 1.--Top: *Atriplex* seeds showing seed damaged by chewing insects. Partial bodies of seed chalcids were found in some seeds. Bottom: Adult chalcids and their exit holes in smooth seeds (*Rhus trilobata* Nutt.) are easier to see than those in *Atriplex* seed.

In order to get an idea of the impacts of insects on the seed of three Atriplex species, seven lots of commercial seed were obtained and analyzed.

Ten one-inch square samples of seed were selected at random from each of the seven lots by pouring the seed evenly over the bottom of a petri dish with a grid in the bottom. The seed was from six geographical locations.

Each seed was clipped into two parts and classified as: (1) good (nondamaged seed); (2) damaged by chewing insects (seed partly eaten or containing dead insects); (3) damaged presumably by sucking insects (brown and shriveled as had been observed in other kinds of seed damaged by insects caged on seed). Some seed was categorized as immature seed (green and shriveled, not discolored or eaten), but this seed was not included in the analyses. A total of 985 seeds were examined. (See tables 4 and 5)

Table 4.--Results of analyses of seven commercial lots of Atriplex seed for insect damage. Data were collected from ten randomly selected 10-inch squares from each seed lot. Species abbreviations are as follows: ATCU=*Atriplex cuneata* A. Nels.; ATGA=*A. gardneri* (Moq.) D. Dietr.; ATCA=*A. canescens* (Pursh) Nutt.; ATCO=*A. confertifolia* (T. and F.) S. Wats.[1]

Section A

Sample/species	Percentage nondamaged seed
Watson, Utah, #1, ATCU	63.5 a
Lincoln County, Wyoming, ATGA	64.1 a,b
Watson, Utah, #2, ATCU	73.5 b
Lincoln County, Nevada, ATCA	81.3 c
Carbon County, Utah, ATCA	84.2 c
Juab County, Utah, ATCO	85.7 c
Sanpete County, Utah, ATCO	100.0

Section B

Sample/species	Percentage of seeds presumably damaged by plant-sucking insects
Juab County, Utah, ATCO	0.0 a
Sanpete County, Utah, ATCO	0.0 a
Carbon County, Utah, ATCA	12.8 b
Lincoln County, Nevada, ATCA	17.1 b,c
Watson, Utah, #2, ATCU	24.1 c,d
Watson, Utah, #1, ATCU	31.0 d,e
Lincoln County, Wyoming, ATGA	34.5 e

(con)

Table 4.-- (con)

Section C

Sample/species	Percentage of seed damaged by chewing insects
Sanpete County, Utah, ATCO	0.0 a
Lincoln County, Wyoming, ATGA	1.3 a,b
Lincoln County, Nevada, ATCA	1.6 a,b
Watson, Utah, #2, ATCU	2.4 a,b,c
Carbon County, Utah, ATCA	3.0 b,c
Watson, Utah, #1, ATCU	5.4 c
Juab County, Utah, ATCO	14.2

[1]Data were converted to percentages based on total number of seeds in a sample and the data transformed using an arcsine-square root function. Analysis of variance and LSD tests @ $P<.05$. Treatment means with the same letters are not significantly different.

Table 5.--Summary of damage due to plant-sucking and chewing insects in each of the seven seed samples. Listing is ranked from lowest to highest overall damage.

Sample/species	Percentage damage		
	Presumed plant-sucking insects	Chewing insects	Total
Sanpete Co., Ut./ATCO	0.0	0.0	0.0
Juab Co., Ut./ATCO	0.0	14.2	14.2
Carbon Co., Ut./ATCA	12.8	3.0	15.8
Lincoln Co., Nev./ATCA	17.1	1.6	18.7
Watson, Ut., #2/ATCU	24.1	2.4	26.5
Lincoln Co., Wyo./ATGA	34.6	1.3	35.9
Watson, Ut., #1/ATCU	31.0	5.4	36.4

ATCU=*Atriplex cuneata* ATGA=*A. gardneri*
ATCA=*A. canescens* ATCO=*A. confertifolia*

Data obtained from evaluating the seed damage shown in tables 4 and 5 were subjected to analysis of variance examination as a completely randomized design, with each location being a treatment and each one-inch square sample being a replicate. Percentage data were transformed using an arcsine-square root function.

A significant difference between treatment means was indicated by data for the seed of all three Atriplex species. Treatment means were examined using a protected LSD test to determine which locations had significantly different percentages of nondamaged and damaged seed. The percentage of each seed type for each location and the results of the LSD tests are shown in tables 4 and 5.

Seed losses attributed to plant-sucking insects ranged from zero (in the Sanpete Co., Utah, sample) to 31 percent (Watson, Utah #1). Losses attributed to chewing insects ranged from zero (Sanpete Co., Utah, sample) to more than 14 percent (Juab Co., Utah, sample). Total losses attributed to insects ranged from zero (Sanpete Co., Utah, sample) to more than 36 percent (Watson, Utah #1).

It appears from the analyses that prospective users of Atriplex seed may expect to encounter a wide variability in seed quality from different sources. Several conclusions may be drawn from this limited, preliminary study: (1) Some customers are paying for nongerminating seed. (2) Seeding rates from some lots of seed will have to be increased to obtain desired numbers of plants. (3) It is likely that new or additional insect pests will be introduced into areas where infested seeds are planted, unless seed is treated to kill the insects. (4) It is probable that large amounts of seed are being destroyed by insects. The 36 percent loss represented by these data does not include damaged seed lost before or during seed collection, or that removed during the cleaning processes, (5) Seed analysts need criteria for determining and certifying quality of native seed, and as a guide for setting seed prices.

There is little doubt that A. canescens seed quality, quantity, and longevity can be increased substantially by appropriate insect control strategies. Proper selection and use of suitable control methods requires: (a) legal registration of pesticides, (b) knowledge about the life cycles and seasonal growth patterns of the plants and insects, and (c) biological facts about other components in the plant's ecosystem.

It appears that one Atriplex seed orchard observed may have been severely infested with mites as a result of the misuse of insecticides. In agriculture it has been a common experience to have crops become infested with mites when insecticides destroyed beneficial insects. The mites have become worse pests than the original target insects (personal experience of authors).

USU ATRIPLEX INSECT COLLECTION

The USU collection of insects associated with Atriplex are primarily from the Bonanza area of Eastern Utah, Ephraim and Nephi, and Curlew Valley, Utah, Idaho Falls, and Kemmerer, Wyoming. The task of obtaining a more complete collection from native and introduced Atriplex species by using various collecting methods to obtain insects from other geographical ecosystems is yet to be completed.

Most of the insects now in the USU rangeland insect reference museum have been collected with insect sweep nets. This means that some insect species present in rangelands may not be represented. Fast-flying insects, those that escape easily (such as grasshoppers), and insects that are nocturnal or that live under the soil surface, may not be collected by sweeping, although the adults of some are. Many insects that were collected in pit-fall traps have not yet been incorporated into the collection. Some other methods of collection have been employed, such as soil samplers, malaise traps, and light traps. Undoubtedly these methods will be utilized more extensively in the future.

Having a representative collection of identified range insects from the western states is an important contribution to the development of new principles of range improvement and management. The USU collection is available to help rangeland managers and others in: (a) setting up collections for specific areas; (b) diagnosing problems; (c) helping select proper combinations of plants for revegetation; (d) selecting insect-resistant varieties; (e) developing improved services from seed laboratories; (f) producing improved quantities and qualities of seeds; (g) calculating economic losses; (h) determining need for pollination; and (i) developing models and management strategies, such as those for predicting yields, integrating growing degree hours into management decisions, and for chemical, cultural, or biological controls.

FACTS ABOUT INSECT COLLECTIONS

It is necessary to have collections from specific areas, such as mine sites, and rights-of-way. Insects found in different plant ecosystems may vary as much as the ecotypes. A centralized collection of insects will be useful, but it will not be likely to contain all the insect species that will have to be identified in solving insect problems associated with rangelands, unless specimens from areas of geographical concern are represented in the collection.

An essential step in solving insect problems on rangelands is identification of the insects involved. The taxonomic task is expensive and largely continuous since insects are commonly spread from one area to another. Programs of interdisciplinary range improvement and management need to include funds for insect taxonomy.

The taxonomic classification of the large number of insect species found in rangelands requires a group of specialists, each of whom may specialize in only one or a few small groups of insects. Identification of insect specimens may require months or years because many rangeland insects are little known or yet to be described. (See table 2)

In order to develop reliable management procedures, it is necessary to know an insect's specific name and major details of its biology.

The assistance of those involved in production, management, and utilization of native plants is needed in collecting insects from these plants in different geographical areas. Insects sent for identification, information, or for inclusion in the USU central collection should be properly labeled with specific locations, dates, host plants, kinds and amounts of damage, and sent to the Range Entomologists, Biology Department, UMC 53, Utah State University, Logan, Utah 84322.

OTHER PROBLEMS AND NEEDS RELATED TO ATRIPLEX AND INSECTS

1. We already are aware of a few insects on Atriplex that appear to be having major impacts on the survival of thousands of acres of fourwing saltbush and shadscale, for example, mealybugs. (See fig. 2) Wyoming Mining Companies and the Idaho Road Commission have reported severe defoliation of fourwing saltbush by chrysomelid beetles (Monoxia elegans) and unidentified caseworms in 1983. (See fig. 3)

Figure 2.--Mealybugs are believed to be responsible for the destruction on hundreds of acres of several species of Atriplex. Note a mealybug with its legs exposed, left, and the dorsal view of another on the right. Bodies of mealybugs are usually covered with waxy substances of various diagnostic designs.

2. There is a need for research and registration of insecticides in order to develop effective controls of native plant insects in greenhouses, on vegetation, in seed being produced, stored, or planted, or on containerized plants and bareroot stock. The legal aspects of applying herbicides on rangelands are well-known to most rangeland managers. There are similar legal restrictions regulating the use of insecticides on rangelands.

In some programs of Atriplex seed production, untested, nonregistered pesticides have been applied regularly, "shot gun" style, to control unknown pests throughout the growing season. These haphazard practices are costly, only partially effective, and ecologically disastrous. For example, some insects develop resistance to insecticides, and plants may become infested with mites that may be more destructive than the original pest insects.

Figure 3.--Top: Atriplex canescens planted in Idaho for roadside rehabilitation was severely damaged in 1983 by a chrysomelid beetle (Monoxia elegans) and an unidentified case-bearing moth. Planting monocultures appears to facilitate insect outbreaks. Bottom: Note pupa of case-bearing moth.

3. Major pests of Atriplex, and their damage, need to be identified, and prioritized for future research.

4. Because of the need for information by commercial enterprises that are planning to establish (or have already established) monocultures of Atriplex, the unique orchards at Ephraim and Nephi, Utah, should be studied by interdisciplinary researchers to obtain basic information comparing seed production of monocultures with that on native rangelands.

5. The cooperation that has begun among state, federal, educational, and private individuals or organizations, needs to continue and increase so that the scope of rangeland research can facilitate the optimal use of Atriplex.

Projects for possible cooperation include: (a) development of methods for producing increased

amounts of high quality seed; (b) development of procedures for processing the seed so that pest insects brought in with the seed are destroyed, and not concentrated at the processing plants or permitted to infest other domestic or native plants; (c) testing ways of protecting stored seed from seed-eating insects; (d) devising methods of fumigating or protecting seed or plants that are sold (from insects originating from processing plant or gathered en route to their destination); (e) determining if application of fungicides or insecticides to seed protects them and increases plant survival in the field.

Solving these problems can reduce costs of range improvement and rehabilitation by increasing success of plant establishment and reducing seeding rates. Customer satisfaction and support of the seed industries is likely to increase if practical recommendations are provided instead of purchases with disclaimer clauses.

6. Seed laboratory personnel have indicated they need new criteria and information to evaluate native plant seeds, formulate standards of classification, and to provide certification of seed purity and germination. Research is needed to solve these problems.

USU studies of caged-injurious insects feeding on native shrub seeds, show that sucking insects that insert their proboscis into the seed may damage vital parts of the seed, presumably by the chemicals they inject and/or by removing materials.

The fed-on seed may be almost full size and appear normal, except for a few discolored spots that may not be noticed by the seed analyst. Some of the damaged seeds show little loss of tissue, and only a small necrotic spot may be visible where the stylets of the insect proboscis entered the plant tissue or seed.

A clip test may show most of the fed-on seed was good. If the insect feeding was in a vital spot in the seed, the seed may not produce a normal plant.

The tasks of seed analysts would be made easier if seeds damaged by caged insects were available to be utilized as examples in classifying seed. Samples of seed shriveled by frost or that is immature should be available for comparison with seed injured by insects.

Damage by chewing insects is usually more obvious and easier to classify than damage by sucking insects. There are many kinds of chewing insects that damage seed--grasshoppers, lepidopterous larvae, adult and immature forms of beetles, and hymenopterans (seed parasites such as chalcids).

Recognizing seeds with live chalcids in them would be helpful to seed buyers because the analysts could recommend that infested seed be treated to prevent the introduction of the seed pests into new areas. (See fig. 1)

Knowing where insect-infested seed comes from, by keeping exact records of purchases, may be helpful to seed producers, collectors, or buyers. The problem of low quality seed may be partially solved if collectors learn to avoid collecting seed in areas that are infested regularly with high populations of injurious insects. (See tables 4 and 5)

CONCLUSIONS

Plant scientists have shown that Atriplex is a valuable plant in many ways for rangeland improvement and rehabilitation of perturbed sites. This review of the status of entomological knowledge related to species of Atriplex suggests that insects are an obstacle to nearly every aspect of this plant's production of vegetation and seed, establishment, and maintenance.

Rangeland insect research at USU at present and for the past few years has concentrated on obtaining a general understanding of the kinds and relative numbers of insects of all plants in rangelands, and getting a broad view of the insects' damage or benefits to range ecosystems (Haws 1982b).

First priority research has been devoted to studies of range grasses and second to bitterbrush, which is a major focus of research at present, but the wide-spread regard for various species of Atriplex shows that these species merit a high priority on the rangeland insect research list.

PUBLICATIONS CITED

Cristi, A. A.; Gasto, C. J. Alteraciones ambientales y del fruto en la germinacion de Atriplex repanda Phil. Universidad de Chile, Facultad de Agronomia, Estacion Experimental, Boletin Tecnico de Agronomia 34: 25-40; 1971.

Furniss, M. M. A preliminary list of insects and mites that infest some important browse plants of western big games. Research Note INT-155. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1972. 16 p.

Furniss, M. M.; Barr, W. F. Insects affecting important native shrubs of the western United States. GTR INT-19. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1975; 64 p.

Haws, B. Austin, Werner, Floyd J.; Capinera, John L.; Lauderdale, Robert W.; Huddleston, Ellis W. An introduction to beneficial and injurious rangeland insects of the Western United States. Special Report 23. Logan, UT: Utah State University Agricultural Experiment Station, Four Corners Commission Publication; 1982a. 64 p.

Haws, B. A. (compiler). Rangeland improvement, demonstration project FCRC No. 602-466-080-4, interdisciplinary integrated pest management (IIPM) research to improve range--lands, management, and policies. Report of Arizona, Colorado, Nevada, New Mexico, Utah, to Four Corners Regional Commission. Logan, UT: Utah State University; 1982b. 282 p.

Hewitt, George B.; Huddleston, Ellis W.; Lavigne, Robert J.; Ueckert, Darrell N.; Watts, J. Gordon. Rangeland Entomology. Range Science Series No. 2. Denver, CO: Society for Range Management; 1974. 532 p.

Knowlton, G. F. The beet leafhopper in northern Utah. Bulletin 23 (Technical). Logan, UT: Utah Agricultural Experiment Station; 1932. 64 p.

Knowlton, George F. Range entomology, an important problem of the west. Entomology Mimeo Series 84. Logan, UT: Utah State University Extension Services; 1966.

McArthur, E. Durant, Plummer, A. Perry; Davis, James N. Wyoming shrublands. Proceedings of the Seventh Wyoming Shrub Ecology Workshop. Laramie, WY: Range Management Division, University of Wyoming; 1978. 50 p.

Monsen, Stephen B. Selecting plants to rehabilitate disturbed areas. IN: R. S. Campbell and C. H. Herbel (eds). Improved range plants p. 76-90. Range Symposium Series 1. Denver, CO: Society for Range Management; 1976.

Palmer, Miriam A. Aphids of the Rocky Mountain Region. The Thomas Say Foundation Volume 5; 1952. 452 p.

Plummer, A. Perry; Monsen, Stephen B.; Christensen, Donald R. Fourwing saltbush, a shrub for future game ranges. Utah State Department of Fish and Game Publ. No. 66-64. Salt Lake City, UT: Utah Department of Fish and Game; 1966. 12 p.

Stevens, Richard; Jorgensen, Kent R.; Davis, James N. Viability of seed from thirty-two shrub and forb species through fifteen years of warehouse storage. Great Basin Naturalist 41(3): 274-278; 1981.

Stoddard, Lawrence A.; Smith Arthur D.; Box, Thadis W. Range management. 3rd ed. New York, NY: McGraw-Hill Series in Forest Resources; 1975. 532 p.

Vallentine, J. F. Range development and improvement. 2nd ed. Provo, UT: Brigham Young University Press; 1980. 545 p.

Watts, J. Gordon; Huddleston, Ellis W.; Owens, John C. Rangeland entomology. IN: Annual Review of Entomology, Palo Alto, CA: Annual Reviews Inc.; 27:282-311; 1982.

In: Tiedemann, Arthur R.; McArthur, E. Durant; Stutz, Howard C.; Stevens, Richard; Johnson, Kendall L., compilers. Proceedings--symposium on the biology of Atriplex and related chenopods; 1983 May 2-6; Provo, UT. General Technical Report INT-172. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 309 p.

USE OF FORAGE SHRUBS IN THE ARID LAND OF CHILE

David Contreras, Patricio Azocar,

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ABSTRACT: Cultivation, overgrazing, and fuelwood removal in the arid IV Region, Coquimbo, Chile, are causing rapid soil degradation and desertification. On those lands where livestock production is now the only feasible land use, Atriplex species are being planted and tested for optimum long-range forage production. It has been found that Atriplex repanda use results in larger lambs and increased milk supply in ewes.

INTRODUCTION

An important area of Chilean rangeland is being affected by a long and strong process of soil degradation and desertification. Approximately 6.9 million acres (2.8 million ha) of dry land make up the arid zone known as IV Region, Coquimbo. In general, relief is dominated by a pattern of alternate valleys and ridges trending east-west, transverse to the dominant longitudinal structure of the Chilean Andes mountains on the east. The coastal range mountains extend on the west, and between the two ranges lies a series of grabens designated as intermediate depressions. The interfluves of these transverse valleys are formed by spurs of the Andes and the coast range.

CLIMATE

The IV Region, Coquimbo, is a mediterranean-type climate. The main disadvantage of the climate, apart from drought and general aridity, is the extreme annual variability in rainfall and the alternation of favorable years with years of serious drought (Di Castri 1968). This area has been defined as having a dry period of 8 to 9 months, 3 or 4 subhumid months in winter, and an absence of cold periods. Droughts lasting 2 to 5 years are not uncommon. La Serena had five serious droughts between 1901 and 1960 (Schneider 1969). Average annual rainfall is so variable that it is difficult to speak of normal rainfall in the IV Region, let alone predict an average. Gasto (1966) calculated that 50.4 percent of the time, the IV Region will have rainfall equal or less than average. Periods of excessive drought have resulted in heavy crop and livestock losses. A period of drought which started in 1967 was responsible for reducing the goat population from 341,000 in 1965 to around 70,000 in 1970 (Aranda 1971). Not only are livestock and natural vegetation losses great during drought, but irrigation water for agriculture activities is scarce, and consequently there are crop losses and damage.

Aridity is a phenomenon of water demand and availability. In the case of the arid land of Chile, water demand by vegetation and crops is high, but availability is restricted by scant rainfall and long dry periods throughout the year. There is a strong belief that the degradation of soil and vegetation in the arid lands has caused decreasing precipitation and drought.

Drought or low rainfall has been named as the main factor responsible for the failure of the systems used to manage agricultural, forest, and range resources. However, it is likely that the present climatic conditions are similar to those found by the Spanish pioneers four centuries ago. A small decrease in average annual precipitation should have had only a very small impact on overall productivity.

VEGETATION

Vegetation, like the topography and climate with which it is so closely associated, varies from north to south and from east to west. Because of the great ecological variability it includes 182 families and nearly 6000 plant species in a pluristratified plant community of trees, shrubs, and annual or perennial range plants. The wild vegetation is mainly low xerophytic scrub, widely scattered columnar cacti, and some evergreen trees. There is a gradual change from widely spaced low shrubs and cacti in the north to a dense mixed-xerophytic and mesophytic chaparral or shrubby formation farther south. This is accompanied by a gradual change in the floristic composition. In most cases, changes in vegetation are less along north-south than along west-east transects, where

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vast ecological changes over short distances are created by differences in relief and elevation. Changes in vegetation along any gradient are a response to elevation, daily sunlight, exposure, soil texture, pH, precipitation, air humidity, graziers, and harvesters.

Floristic components were quite different in the past. The herbaceous strata has been severely affected by cultivation and overgrazing. Many plant species have disappeared or are rare. Dominant plant genera are: Erodium, Vulpia, Oxalis, Plantago, Avena, Calandrina, Cryptantha, Gnaphalium helenium, Koeleria, Adesmia, Pectocaria, and Silene. These are exotic plants introduced from Europe. There are still native range plant species of the genera Trisetobromus, Bromus, Lolium, and Medicago. Some almost extinct species are: Trifolium, Trigonella, Hosakia, Stipa, Nassella, and Festuca. Generally speaking, the process of intensive utilization and mismanagement of natural plant communities, especially during the past 200 years, has resulted in degraded and lower successional climax vegetation on most of the Chilean arid land.

In contrast to popular notions, there is no evidence to suggest that most of the arid land in Chile was forested during prehistoric times. Aside from areas that have been completely cleared, there are sites where endemic shrubs and trees exist, probably with a physiognomy very similar to that encountered by the Spanish pioneers. Most of the areas considered as arid land in Chile are low in biomass production and dependent upon the amount and distribution of precipitation, successional stage, and condition of the vegetation. Average pasture production on arid land is about 1.7 to 3.0 ton/acre (0.7 to 1.2 ton/ha) dry matter per year.

The nutritive value of available forage varies widely through the year and is correlated with the phenology and floristic cómposition of the plant community. Energy is the second most limiting factor for livestock production and fluctuates between 1.2 and 2.5 k. cal/gr. dry organic matter. Protein content is also a limiting factor, especially during the dry periods. Before the pasture plants bloom their protein content is about 10 to 14 percent; this decreases to 3 to 4 percent after plant dry out. Crude protein can fluctuate from 10 to 30 percent for the same period.

LIVESTOCK

Annual productivity, according to current ecological conditions, allows only the development of extensive grazing operations, mainly goats and sheep. In areas where the degradation is great, farmers raise goat flocks, produce cheese, and sell kids during the spring. Small flocks of sheep are present in areas with high pasture potential along with coastal ranges. Average stocking rate varies from 0.25 to 0.75 head/acre (0.1 to 0.3 head/ha).

Continuous and heavy human pressure on the ecosystem either through wood harvesting, soil cultivation on marginal land, or overgrazing, has produced an accelerated erosion process which in many situations cannot be easily stopped or reversed. Overgrazing has caused an increase in the death rate of palatable plant species along with a decrease in the reseeding rate and recovery rate. On the other hand, nonpalatable plants and weeds have increased growth and population, thus reducing productivity and carrying capacity. Other factors affecting floristic changes were cropping of marginal soils for cereals and other dryland crops such as cumin seed, and harvesting woody plants and trees for domestic purposes.

In order to illustrate how the above-mentioned practices relate to the present state of the coastal terraces, an algorithm (fig. 1) was designed. It suggests the fundamental changes that have occurred in the area (Gasto and Contreras 1979).

The vegetation found in the most degraded areas at the present time consists of plant species belonging to genera Plantago, Dicondra, and Erodium. Periodic plowing eradicated the woody and shrub species, increasing soil erosion and generating retrogressive processes. Plowed soils are fallowed one year before cereals are cultivated. Those species of plants most demanded by animals are often diminished. Sites where soil fertility is depleted are then abandoned and used for goat grazing. The extension of cultivation is always toward places that have been abandoned, generally for more then 20 years. The degraded and abandoned areas are finally invaded by Cassia coquimbensis Vogel (alcaparra); Bahia ambrosioides Lag. (chamisa); Haplopappus angustifolius (D.C.) Reiche (bailahuen), and other plants.

The degradation of the coastal terrace ecosystem began late in the sixteenth century with the introduction of cattle, sheep, and later, goats. The most destructive agents were the introduction of animals resistant to drought, soil cultivation on marginal lands, and harvesting trees and shrubs for firewood. The construction of the Pan American highway through the coastal range in 1950 allowed new access to vast areas, resulting in explosive use of these lands for grain production. The characteristic states of this degradation are shown in figure 1 and can be described as follows:

- climax ecosystem of hemicriptophytes dominated by bunchgrasses such as Nassella chilensis (Trind) Desv.; Pictochaetum stipoides (Trind & Rupr.) Hackd; Stipa plumosa Trin, Stipa lackmophylla Trind and Bromus mollis L.

- reduction of hemicriptophyte biomass.

- invasion of areas by woody shrub plants such as Baccharis concava (R. & Pav.) Pers; Baccharis linearis (R. & Pav.) Pers; Haplopappus anguistifolius (D.C.) Reiche; Trevoa trinervis, Miers.

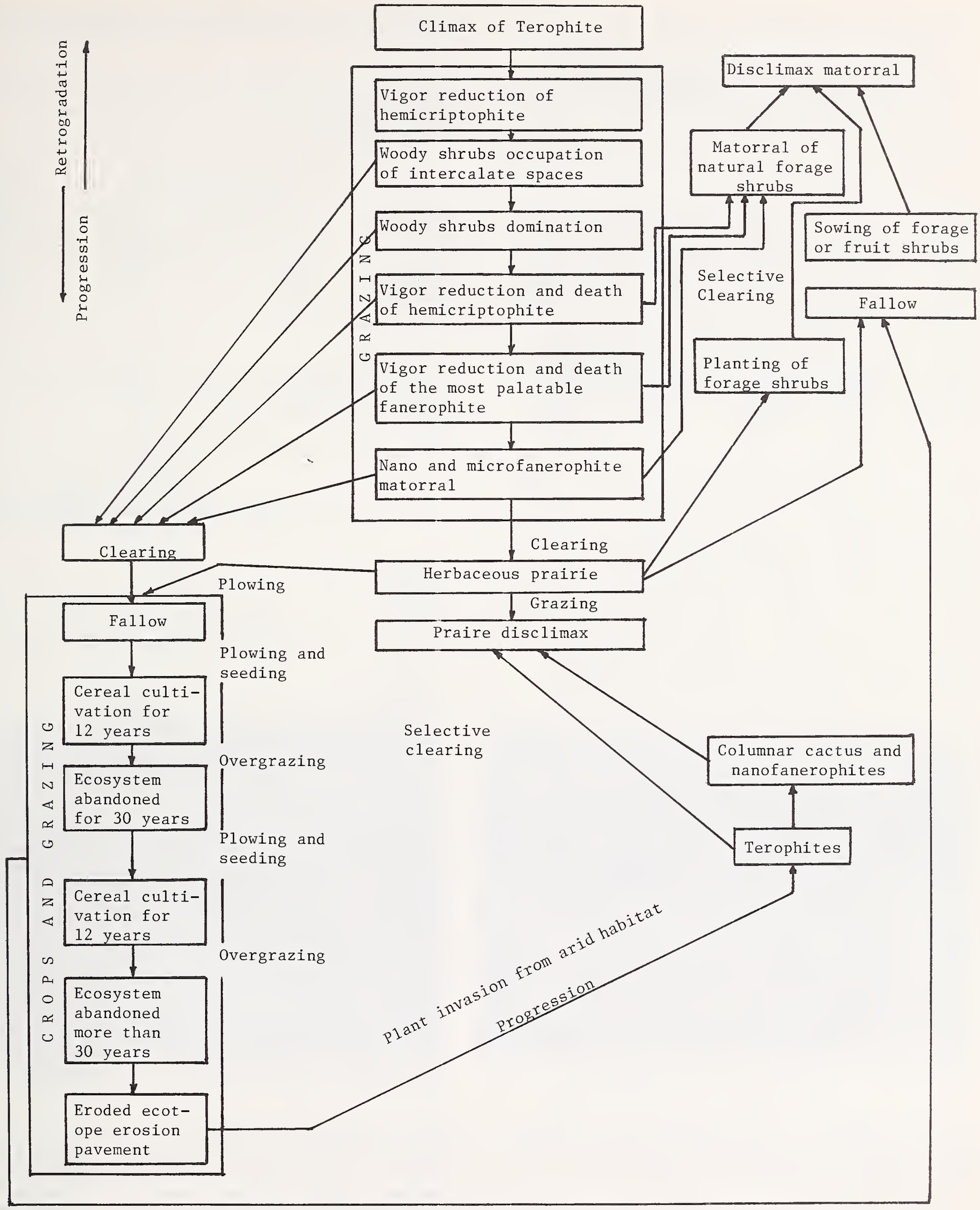

Figure 1.--Scheme diagram of the retrogression of ecosystem in the coastal terrace range, IV Region, Chile. (Gasto and Contreras 1979).

- plowing in successive stages.
- abandoned sites and invasion of cactus species such as Trichocerius chilensis (colla) (Br & R.); Puya chilensis Mol,; and Puya berteroniana Mez.

SHRUB REPLACEMENT

In 1958, the University of Chile, Faculty of Agrarian, Veterinary, and Forestry Science began an evaluation and inspection/search of shrub plant species for livestock forage in a large area of the arid land. The adopted strategy was oriented to suggest species to replace the unpalatable woody shrubs. The most promising native species found from north to south were: Atriplex deserticola Phil.; Atriplex micophylla Phil.; Atriplex atacamensis Phil.; Atriplex coquimbaria Phil.; Chenopodium paniculata Phil.; and Atriplex repanda Phil.

The native Atriplex repanda, also known as "sereno," is a good shrub found in the arid lands of the coastal range. It has a high palatability which almost produced its extinction. It grows year-round and has fast regrowth in summer, minimal growth in late fall and winter. Nutritive value is high. Protein content is 18-20 percent in leaves, 11-12 percent in stems, and 9 percent in seeds. The average crude fiber content is 23 percent. Characteristics of "sereno" include: high resistance to dry conditions, green forage and protein availability during the dry period, and high palatability.

Low seed germination was found in Atriplex repanda. Germination was less than 5 percent under natural conditions. Soaking seeds in sulfuric acid was observed to improve seed germination up to 35 percent. The results indicate that seed age has an important role in seed germination. One-year-old seeds need 7 hours soaking, while 5-year-old seeds need only 2 hours soaking (Olivares and Johnston 1978).

SHRUB-LIVESTOCK STUDIES

Studies were conducted to compare grazing intensity. A grazing trial was oriented to evaluate when and how many times shrubs should be grazed in order to get the best response in terms of plant longevity. Results indicate that the shrub Atriplex repanda could be grazed any time of the year, but only once for maximum productivity and longevity. When grazed twice a year, forage production is high but plants are affected; vigor, regrowth, and population density are reduced (Di Marco 1973).

Another problem in introducing Atriplex repanda is timing the integration of this supplementary forage into the annual cycle of livestock. It has been seen that pregnant ewes perform better when they graze on repanda during the last third of their gestation period. Lambs are born with greater weight. Growth also is faster, indicating an effect on milk lactation (Rodriguez and Gasto 1972; Duchens and Cuneo 1980) (Tables 1,2,3).

Table 1.--Percentage of ewes giving birth in two different pasture types, 1972 (Rodriquez and Gasto 1972).

Type of pasture	Births: Single	Births: Double (twins)	Total of ewes lambing
	Percent		
Shrubs	61.7	32.3	94.0
Prairie	76.4	11.7	88.0

Table 2.--Average lamb weight by pasture type and carrying capacity, from birth to 4 months old (Duchens and Cuneo 1980).

	Lamb weight: Birth	1st month	2nd month	3rd month	4th month
	Kg				
Type of pasture					
Pasture	4.1	8.7	15.4	23.9	31.1
Shrub	4.6	8.7	15.6	23.7	32.2
Carrying capacity					
0.5 sheep/ha/ year	4.7	10.1	16.3	24.3	31.6
2.0 sheep/ha/ year	4.0	8.4	14.7	23.2	31.7

CONCLUSIONS

After 15 years of research and studies it can be concluded that it is possible to replace some of the nonpalatable floristic components of the natural dry land ecosystem in Chile with shrubs such as Atriplex repanda and Atriplex nummularia without altering the structure and functioning of the ecosystem. Restricted management of the shrub species produces improved herbaceous pasture.

As a result of these studies, the National Forest Corporation (CONAF) has started a plantation program in the arid coastal range of Chile (IV region, Coquimbo) in cooperation with private entities. During 1976, 63.5 acres (25.7 ha) were planted. Large amounts of money have been invested by CONAF and land owners for forage shrubs to ensure green forage during critical periods (fig. 2,3).

Table 3.--Associated effects on sheep weight of pasture type, carrying capacity, and birth type (Duchens and Cuneo 1980).

		Sheep weight					
		Initial	Birth	1st. Mo.	2nd Mo.	3rd. Mo.	4th. Mo.
		kg					
Type of pasture	Carrying capacity						
Shrub	0.5 sheep/ha/yr	59.3	58.1	53.3	55.7	59.8	62.6
Pasture	0.5 " " "	59.4	53.6	50.8	55.8	59.5	62.1
Shrub	2.0 " " "	59.7	52.2	51.5	53.9	59.3	66.5
Pasture	2.0 " " "	58.9	48.8	47.9	52.1	59.1	63.2
Type of pasture	Birth						
Shrub	One	--	57.6	53.6	56.2	60.2	63.6
Pasture	One	--	52.6	51.1	55.5	61.2	63.6
Shrub	Twins	--	52.8	51.2	53.4	59.0	65.5
Pasture	Twins	--	49.8	47.6	52.3	57.4	61.7
Carrying capacity	Birth						
0.5 sheep/ha/yr	One	--	57.0	53.6	58.1	62.3	64.9
2.0 " " "	One	--	53.2	51.0	53.7	59.0	62.3
0.5 " " "	Twins	--	54.7	50.0	53.5	57.0	59.8
2.0 " " "	Twins	--	47.8	48.4	52.3	59.4	67.4

(A)

(B)

Figure 2.--Shrub plantation in the IV Region, Coquimbo, under the National Forest Corporation Program 1976-83. (A) Slopes denuded by crops and overgrazing by goats, (B) contour furrows planted with 2-year-old shrubs.

Figure 3.--Six-year-old plantation of Atriplex nummularia grazed by goats in the arid IV Region, Coquimbo.

PUBLICATIONS CITED

Aranda, Ximena. Algunas consideraciones sobre le trasumancia en el Norte Chico. Informaciones Geográficas. 20: 14-169; 1971.

Bahre, J. & C. Destruction of the natural vegetation of Northcentral Chile. Geography. Vol. 23. University of California Press; 1979.

Di Marco, A. O. Consumo y preferencia ovina estacional al aumentar la intensidad de pastoreo en una bioma biestratificado con Atriplex repanda Phil. Santiago: Universidad de Chile; Programa Permanenta para Graduados de la Republica de Chile; 1973. Tesis Mg Ss.

Duchens H.; Cuneo, J. Utilización porovinos de una pradera natural biestratificada con Atriplex repanda Phil. durante el último tercio de prenez de gestacion. Santiago: Facultad de Agronomia, Universidad de Chile; 1980. Tesis Ingr. Agr.

Gasto, Juan. Variación de las precipitaciones Anuales en Chile. No. 24. Santiago: Estación Experimental Agronomica, Universidad de Chile; 1966

Gasto, J.; Contreras, D. Un caso de desertificacion en el norte de Chile. El ecosistema y su fitocenosis. Boletin Tecnico No. 42. Santiago: Universidad de Chile, Facultad de Agronomia; 1979.

Olivares, A.; Johnston M. Alternatives de megoramiento en la emergencia de Atriplex repanda Phil. Phyton. 36 (2): 129-137; 1978.

Paskoff, Roland. Recherches geomorphologiques dans le Chili semi-aride. Bordeaux: Biscaye Freres; 1970.

Rodriguez, E.; Gasto J. Estudio del efecto del consumo de pradera natural biestratificado con Atriplex repanda Phil. en el periodo de encaste de ovinos. Santiago: Facultad de Agronomia, Universidad de Chile; 1972. Informe interno.

Schneider, Hans. El clima en el Norte Chico. Santiago: Facultad de Educación, Universidad de Chile; 1969.

In: Tiedemann, Arthur R.; McArthur, E. Durant; Stutz, Howard C.; Stevens, Richard; Johnson, Kendall L., compilers. Proceedings--symposium on the biology of Atriplex and related chenopods; 1983 May 2-6; Provo, UT. General Technical Report INT-172. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 309 p.

Section 7. Revegetation

PERFORMANCE TESTS OF FOURWING SALTBUSH TRANSPLANTS IN EASTERN OREGON[1]

J. Michael Geist and Paul J. Edgerton

ABSTRACT: Recent steps have been taken toward improving the diversity and abundance of forage for livestock and big game on historically depleted foothill ranges in eastern Oregon. Fourwing saltbush (_Atriplex canescens_ [Pursh] Nutt.) is being evaluated for a potential role in this effort. The results have been positive and encouraging.

The adaptability of 3 seed sources of this species was observed for 5 years in a uniform garden setting. 'Rincon' fourwing saltbush, a New Mexico source, performed best. Subsequent tests using 'Rincon' transplants were conducted to evaluate adaptability to various sites under different conditions of competition control. Survival was enhanced by competition control in one experiment but not in a second. First season average height growth of spring transplants was doubled with competition control, was nearly double at the end of 2 seasons, and average plant weight was 4 to 10 times greater with competition control after 2 seasons. All results indicate a high potential for the use of 'Rincon' fourwing saltbush in rehabilitation of these ranges.

INTRODUCTION

As with many areas of the Western United States, eastern Oregon rangelands could benefit from diversified and increased food supplies for wild and domestic ungulates. Greater diversity in vegetation can improve seasonal forage quality and may even contribute to greater vegetative stability (Margalef 1969). This paper reviews efforts in pursuit of such benefits on shrub-steppe ranges in eastern Oregon. This research is somewhat restricted in scope, but we believe it has broader applicability and should help both public and private land managers with their resource decision-making.

These depleted Oregon ranges are generally dominated by less desirable forage plants such as cheatgrass brome (_Bromus tectorum_ L.), medusahead wildrye (_Elymus caput_ var. _medusae_ L.), Japanese brome (_Bromus japonicus_ Thunb.), various subspecies of big sagebrush (_Artemisia tridentata_ Nutt.), rabbitbrush (_Chrysothamnus_ spp. Nutt.), and a variety of forbs. Some ranges have been successfully seeded to domestic grasses, usually crested wheatgrass (_Agropyron desertorum_ Schult.), to increase available forage and reduce grazing pressures on remnants of preferred native perennial plants. However, such seedings commonly lack a suitable variety of forage or wildlife cover. The purpose of our research is to provide knowledge about opportunities to improve these less desirable rangeland conditions.

The Keating range in Baker County, Oreg., is typical of foothill areas where vegetation improvement has been a long standing concern. It includes 45,000 acres (18 218 ha) of crucial deer winter range containing a mosaic of depleted sites and extensive grass seedings. Winters are cold and windy, summers are hot with a pronounced July-August drought. Precipitation occurs mostly in winter and spring, principally as snow. Fall precipitation is unpredictable but sometimes significant. Annual precipitation is variable, but at our study sites averages about 12 inches (30 cm). Mule deer winter on the range from December through March. Livestock, mostly cattle, graze in a variety of management systems, generally from mid-April to late July. Livestock may return between November and January depending on the annual production and whether fall precipitation stimulates late regrowth. Our study sites occur within the crucial winter range area.

We have been determining the potential of fourwing saltbush (_Atriplex canescens_ [Pursh] Nutt.) for foothill range improvement. It is widely recognized in the Western United States as a valuable shrub to be included in rangeland plantings on a

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variety of ecological sites (Plummer and others 1966; Springfield 1970).

The results of 3 related experiments are reported. (1) An adaptability trial begun in 1976 to screen 3 fourwing saltbush accessions in a uniform garden, (2) an establishment trial begun in 1981 to compare site preparations at the same location utilizing the most promising of the above 3 accessions, and (3) an adaptability/establishment trial begun in 1982 with the same accession as in (2) to compare site preparations and performance over a broad portion of the Keating range.

INITIAL ADAPTABILITY TRIAL

Thirty individuals from 3 sources were transplanted into a 6-ft (1.8-m) grid in the Keating uniform shrub garden in the spring of 1976. The 3 sources were: Decker, Mont., a relatively high-elevation, cool, moist location; Moreno Valley, Calif., a low-elevation, dry, hot location; and Rincon Blanco, N. Mex., a relatively high-elevation, cool, moist location. The Decker source was known to exhibit a more prostrate growth form. Plants were obtained from the USDA Forest Service, Intermountain Forest and Range Experiment Station, Shrub Sciences Laboratory, Provo, Utah.

The New Mexico source has been evaluated by researchers and land managers in plantings and seedings on a variety of sites in the Intermountain West (McArthur and others 1983). Its superior adaptability and performance as a forage and reclamation plant has merited plant selection and seed release by the USDA and cooperating agencies for commercial production and marketing of seed and plants (McArthur and others 1982). The selection has been released under the name 'Rincon' fourwing saltbush. We used the 'Rincon' selection in our trials.

The garden area is protected by a deer-proof fence. The site was initially moldboard plowed and disced just prior to planting, and has been annually cultivated since. Standing vegetation was an established crested wheatgrass seeding, but nearby unseeded range suggests the area prior to seeding was a basin big sagebrush/cheatgrass brome/weedy forb stand with scattered rabbitbrush. Soils are deep with silt loam surface texture grading to clay loams in lower horizons and then to weathered granitic materials of coarse sand and gravel size. The soil parent material is dominantly granitic outwash, but apparently was surface influenced by silt-sized volcanic ash of unknown origin. The outwash material extended beyond 5 ft (1.5 m) deep. No irrigation water or fertilizer was applied.

Plants were measured in the fall of each year for maximum height growth and crown spread and assessed for survival. Green weight estimates were made to provide an additional comparison of plant sizes.

Statistical comparisons were not made because this was a case history. We have presented only means and standard deviations of the plant parameters measured.

Results of Adaptability Trial

Ideal conditions afforded by cultivation, protection from ungulate browsing, and deep soils yielded excellent survival (93-100 percent) over the 5-year period. Average height and crown spread of the California and New Mexico sources were very similar, and both were about 2 times the size of the prostrate form obtained from Montana (table 1). Green weight estimates indicated the average growth rate of the New Mexico source was greater than the California source which, in turn, outgrew the Montana source. Both the New Mexico and California sources showed indications of being fast starters which is important in relation to the dry period in the summer. Only the Montana plants flowered the first year (about 53 percent). All sources flowered at about 50 percent in year 2 and 86 percent or more in ensuing years.

In follow-up evaluations it was decided to use only 1 source. Given the widespread success of the New Mexico source and the excellent local performance we observed, it was chosen for further evaluations described below.

ESTABLISHMENT TRIAL

Knowledge about the benefits of competition control to plant establishment was considered necessary in preparation for future tests of outplanting success. Thus, the effects of 3 site preparation treatments on the growth and survival of 'Rincon' fourwing saltbush were compared in the Keating garden exclosure. Treatments were: no preparation (control), spot scalp, and spot spray. Three replicates of the treatments were assigned in a completely random fashion to nine 18- by 66-ft (5.5- by 20.1-m) plots containing 30 transplants each. Transplants were made on a 6- by 6-ft (1.8-by 1.8-m) grid spacing within plots. Treatment spots were approximately 3 ft (1 m) square; scalps were about 1 inch (2.5 cm) deep. Roundup herbicide was applied to the foliar wetting point with 2 passes from a backpack sprayer at a concentration of 4 fluid oz (118 ml) of herbicide concentrate (1.64 oz [48 ml] active ingredient) and 2 oz (59 ml) of No Foam B sticker per gallon (3.8 l) of water. Scalping and planting were done in late April 1981, 2 days after

Table 1.--Fourwing saltbush source comparisons at the Keating Uniform Garden over a 5-year period. Data are means from about 30 plants.

State	1976	1977	1978	1980
	Maximum height - means (standard deviations), inches			
Montana	9 (4)	18 (3)	20 (4)	20 (5)
California	25 (5)	35 (5)	41 (6)	46 (9)
New Mexico	25 (6)	35 (4)	42 (6)	49 (7)
	Maximum crown spread - means (standard deviations), inches			
	1976	1977	1978	1980
Montana	23 (13)	40 (8)	46 (10)	43 (12)
California	46 (16)	64 (13)	76 (18)	81 (17)
New Mexico	40 (14)	58 (12)	76 (17)	89 (19)
	Estimated green weight - means (standard deviations), pounds			
	1976	1977	1978	1980
Montana	0.4 (0.4)	1.0 (0.6)	2.0 (1.3)	2.8 (2.5)
California	1.2 (0.8)	3.1 (1.3)	9.9 (5.7)	8.1 (3.7)
New Mexico	1.2 (0.8)	4.7 (3.0)	11.8 (6.5)	12.5 (10.6)

spraying. All operations were done by hand in a single day. Soils were moist at that time. Seedlings of target annual grass and weed species were approximately 1 inch (3 cm) high.

Plants were checked for survival and maximum height measured in the fall each year. Layered canopy cover estimates were made prior to spraying and at the end of the second season on center rows of plots by the method of Daubenmire (1959). Plants were harvested 2 years later at the end of September 1983 for production comparisons. They were clipped at ground level, ovendried at 131°F (55°C) and weighed. Mean values reported for height and weight were computed on the basis of live plants only.

The results were tested by one-way analysis of variance and Scheffe's test of means at the 95 percent level of confidence (Freese 1967).

Results of the Establishment Trial

Data from 2 growing seasons indicate survival percentages of plants on the control plots were about one-half, height (maximum) growth was one-half or less, and dry weight was much less when compared to plants on the other treatment plots (table 2). The height of spray treatment plants exceeded that of scalp treatment plants after the first season, but not the second. Spray treatment plants substantially exceeded scalp treatment plants in top weight after 2 growing seasons. There was relatively little change in survival from the first to the second season. Plants in this trial grew slower than those in the adaptability trial noted above. We suspect this was mostly because of decreased competition through cultivation of weeds in the adaptability trial; however, differences in climatic factors from prior years may also have contributed.

Competition was essentially controlled by spraying or scalping the season of treatment, but reinvasion was evident by the end of season 2 (table 3). Canopy coverage of herbaceous vegetation that invaded scalp and spray spots was commonly little different from control spots. This indicates a limited time effectiveness of competition treatments.

Table 2.--Comparison of fourwing saltbush transplants of the New Mexico source over 2 growing seasons, under 3 site preparations, in the Keating garden exclosure. Values for height and weight are means of the survivors from the 90 transplanted seedlings.

Characteristic		Control	Scalp	Spray
Survival (%)	- 1981	43a[1]	99b	87b
	- 1982	37a	87b	86b
Height (inch)	- 1981	6a	12b	17c
	- 1982	15a	21b	29b
Dry weight (oz)	- 1982	0.6a	2.6b	6.7c

[1] Mean values in the same line followed by different letters are significantly different ($P < 0.05$).

Table 3.--Percentages of layered canopy cover[1] at the end of the second growing season (1982) for the Keating Garden establishment trial.

	Vegetation class				
Treatment	Overall	Annual grass	Perennial grass	Forbs	Planted shrubs
Control	95	72	12	61	2
Spray	89	57	0	59	27
Scalp	80	46	2	54	17

[1] Layered canopy cover can exceed 100 percent when values for individual species or species groups are summed; however, the vertical overlapping of layers of foliage precludes our ability to simply add or subtract these values. We did not obtain an overall layered canopy cover ignoring the planted shrubs and this is a regrettable oversight because we found this of interest later. We felt this might be more reflective of competition control.

ADAPTABILITY/ESTABLISHMENT TRIALS

The first step in gathering data on the general outplanting performance of fourwing saltbush was taken with trials begun in April 1982. These trials included 5 locations at which the New Mexico accession was planted into an unsprayed (control) plot and into spots sprayed with Roundup herbicide. Treatment plots contained 75 plants arranged in 5 rows and spaced on 6-ft (1.8-m) centers. The 2 randomly assigned treatments were placed side by side and were replicated at 5 locations spanning a sizable portion of the Keating range. Experimental design was, thus, a randomized block with locations representing blocks. The spray spot remained the same size and application rate was also the same as used in the previous establishment trial. Four of the 5 locations were fenced from cattle grazing, but all were accessible to deer. Some protection from livestock use at the fifth location was afforded by a single-strand, 3-sided barbed wire barricade used to divert off-road vehicle traffic. Plant performance was measured and calculated as in the adaptability trial after 1 growing season in late September 1982. Degree of exposure to wild animal use is unknown.

Site factors associated with locations afforded a variety of soil and vegetative conditions under which to test performance of transplants (table 4). Some were recently disturbed, others had been disturbed by some previous management practice including seeding, but documented histories for the areas are lacking. Soil surveys are being conducted in the general area, but no correlated classifications are available.

Table 4.--General characteristics of sites associated with initial outplanting of fourwing saltbush on the Keating range in Baker County, Oreg.

Location	Elevation	Slope	Aspect	Vegetation supported	Soil
	Feet	Percent	Degrees		
Ritter	2920	4	125	Agropyron desertorum Artemisia tridentata	Moderately deep; surface texture - loam to silt loam
Tucker	3018	6	186	Bromus tectorum Amsinckia spp. Erodium cicutarium	Shallow to moderately deep; surface texture - clay loam; swelling
Lowar	2759	8	133	Bromus tectorum Cardaria spp.	Deep; silt loam surface and sub-surface texture; volcanic ash parent material
Smallex	3159	17	240	Bromus tectorum Elymus caput-medusae Sisymbrium spp.	Moderately deep mixed outwash of mainly granitic origin; surface texture - loam
Hollow	3041	14	84	Elymus caput-medusae Sisymbrium spp.	Moderately deep to deep; surface texture - clay loam; swelling

Containers having 10.5-inch^3 (175-cc) cells were used to produce the transplants for the 5 pairs of treatment plots. In addition, at only the Hollow location, 2 sets of 25 transplants grown in 21.5-inch^3 (350-cc) containers were used to determine whether larger containers held any advantage over smaller containers. A randomly predetermined subset of two 25-plant blocks in the smaller container planting was used for comparison with the same number of larger container transplants. The Hollow location was chosen because it was thought to be an especially difficult revegetation situation.

Statistical tests used were analyses of variance and Scheffe's test of means with significance determined using a 5 percent significance level.

Results of the Adaptability/Establishment Trial

Site preparation by spraying did not significantly affect survival over all plots, but spraying markedly affected height growth (table 5). Had standing crops been sampled, the differences reflected by dry weights would have been even greater. As in the trial discussed above, plants in the unsprayed plots were frequently healthy though relatively small; their vigorous appearance indicated they would likely survive the ensuing winter. The poorest survival among the 5 locations was 55 percent without spraying and 75 percent with spraying.

Plant competition along the edges of the spray spots grew better in response to competition control. Thus, spraying in itself produces structural changes in adjoining vegetation. Spraying was lethal to all plants contacted, and we found complete kill of a sagebrush plant required full and thorough coverage of the plant canopy.

Data from the container comparison conducted at the Hollow site were similar to overall trends. No differences were found in survival (ranged from 88 to 100 percent), but growth was greater where competing vegetation was reduced by spraying. In addition, a

significant ($P < 0.05$) interaction was detected between spray and container treatments. Transplants from larger containers grew taller in the control plots, but the mean heights of plants from the 2 container sizes were nearly identical in sprayed plots. Smaller container plants grew more in response to competition control (table 6).

Table 5.--Fourwing saltbrush transplant performance averaged over 5 locations after 1 growing season. Values for height are the overall means of survivors from 375 seedlings transplanted per treatment.

Characteristic	Control	Spray
Survival (%)	78a[1]	88a
Height (inches)	6a	14b

[1]Mean values in the same line followed by different letters are significantly different ($P < 0.05$).

Table 6.--Mean values of maximum height of fourwing saltbush transplants in the container size comparison trial at the Hollow site after 1 growing season, 1982.

Container size	Control	Spray
	--------inches----------	
Small (175 cc)	5	12
Large (350 cc)	8	12

DISCUSSION AND CONCLUSIONS

The excellent performance of fourwing saltbush suggests this species could play a significant role in upgrading problem areas of the Keating range. Widespread establishment of this plant could benefit livestock and big game forage supply and provide cover for upland game birds and possibly other nongame species.

Competition control seems to be necessary to assure vegetation improvement on these ranges. This finding is similar to those of other researchers (Holmgren 1956; Hubbard 1957). Control likely will benefit growth and in some years may also promote increased survival of container stock. Presuming environmental compatibility of herbicide treatment, we would recommend this practice over scalping because of time and labor advantages. Roundup herbicide only controls, however, vegetation growing at the time of application. Carryover effects the second season may occur, but the extent is unpredictable. Reinvasion of spray spots invariably occurred in the second season. Spray spots retained litter cover as an evaporative and thermal barrier and litter also helped soil erosion resistance. Nutrient-rich topsoil remained in place with spraying also. Scalped spots seemed to have no advantage over sprayed spots. Scalp depth was hard to control and scalping was more time consuming.

Rapid growth exhibited by the 'Rincon' plants in our experiments is an especially desirable characteristic for establishment on northwest rangelands with low growing season precipitation. Rapid growth is essential to take advantage of available stored soil moisture before evaporative losses occur.

Our work with 'Rincon' saltbush suggests the adaptability of this shrub is widespread and excellent. Extensive transplanting may not be a feasible management alternative, so future research should concentrate on evaluating other establishment practices to facilitate the use of this promising shrub.

PUBLICATIONS CITED

Daubenmire, R. A canopy - coverage method of vegetational analysis. Northwest Sci. 33: 43-64; 1959.

Freese, Frank. Elementary statistical methods for foresters. Agriculture Handbook 317. Washington, DC: U.S. Department of Agriculture, Forest Service; 1967. 87 p.

Holmgren, Ralph C. Competition between annuals and young bitterbrush (Purshia tridentata) in Idaho. Ecology 37(2): 370-377; 1956.

Hubbard, Richard L. The effect of plant competition on the growth and survival of bitterbrush seedlings. J. Range Manage. 10(3): 135-137; 1957.

McArthur, E. D.; Hassell, W. G.; Stevens, R.; Davis, J. N.; Stronathan, S. E.; Noller, G. L.; Tiedemann, A. R.; Goodrich, S. K. Notice of naming and release of 'Rincon' fourwing saltbush (Atriplex canescens) for wildlife and livestock range and disturbed land rehabilitation. Washington, DC: U.S. Department of Agriculture, Soil Conservation Service; 1982. 5 p.

McArthur, E. D.; Stevens, R.; Blauer, A. C. Growth performance comparisons among 18 accessions of fourwing saltbush (Atriplex canescens) at two sites in central Utah. J. Range Manage. 36(1): 78-81; 1983.

Margalef, Ramon. Diversity and stability: a practical proposal and a model of interdependence. In: Diversity and stability in ecological systems. Brookhaven Symposium on Biology 22. Upton, NY: Brookhaven National Laboratory; 1969; p. 25-37.

Plummer, A. Perry; Monsen, Stephen B.; Christensen, Donald R. Fourwing saltbush - a shrub for future game ranges. Publ. No. 66-4. Salt Lake City, UT: Utah State Department of Fish and Game; 1966. 12 p.

Springfield, H. W. Germination and establishment of fourwing saltbush in the Southwest. Res. Pap. RM-55. Ft. Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1970. 48 p.

In: Tiedemann, Arthur R.; McArthur, E. Durant; Stutz, Howard C.; Stevens, Richard; Johnson, Kendall L., compilers. Proceedings--symposium on the biology of Atriplex and related chenopods; 1983 May 2-6; Provo, UT. General Technical Report INT-172. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 309 p.

NURSERY PROPAGATION AND OUTPLANTING OF BAREROOT CHENOPOD SEEDLINGS

Nancy Shaw and Stephen B. Monsen

ABSTRACT: Cultural practices for growing bareroot chenopod transplant stock and results of two outplanting trials are discussed. Acceptable seedlings of several species can be propagated, but erratic seed germination and morphological characteristics of the seedlings can create production problems. Additional work is required to refine techniques for growing each species. Bareroot stock of fourwing saltbush (Atriplex canescens [Pursh] Nutt.), winterfat (Ceratoides lanata [Pursh] J.T. Howell), and several other shrub and forb species were successfully intertransplanted into a crested wheatgrass stand using a mechanical treeplanter. Excellent survival of adapted species and adequate control of competition were attained with this technique.

INTRODUCTION

Disturbances of arid shrublands result from natural events and the increasing impacts of human activity. Natural recovery proceeds slowly and seeding in areas that receive less than 10 inches (25 cm) annual precipitation is risky (Bleak and others 1965; Holmgren 1973). Depending upon planting objectives and financial considerations, transplanting may be employed to more rapidly and reliably restore native species, initiate processes such as litter accumulation and nutrient cycling, stabilize erodible soils, increase forage production, provide wildlife habitat, and meet legal requirements for reclamation. Transplants are usually more tolerant of drought, competition, salinity, soil crusting, predation by rodents or big game, late frosts, and other adverse conditions than are newly emerged seedlings and may be used to minimize or avoid these and other problems associated with direct seeding (McKell and Van Epps 1981; Ferguson and Frischknecht 1981; Stevens and others 1981b).

Shrubby chenopods dominate salt-desert shrublands and are widespread on rangelands of the Western United States. Seed and transplant stock of adapted chenopods have been used for the reclamation of areas disturbed by mining (DePuit and Coenenberg 1979; Aldon 1981; Ferguson and Frischknecht 1981). Transplants may also be used to restore restricted rangeland sites such as holding or trailing areas, intermittent waterways, and portions of critical winter ranges that are difficult to seed or inaccessible to seeding equipment. Fourwing saltbush (Atriplex canescens [Pursh] Nutt.), winterfat (Ceratoides lanata [Pursh] J.T. Howell), and other chenopods have been propagated as low water use ornamentals for landscaping projects, roadways, campgrounds, and recreation areas on arid lands (Stark 1966; Steger and Beck 1973). Intertransplanting or interseeding Fairway crested wheatgrass (Agropyron cristatum [L.] Gaertn.) and standard crested wheatgrass (Agropyron desertorum [Fisch.] Schult.) stands with fourwing saltbush has increased forage production and improved the quality and diversity of cover for livestock and wildlife (Monsen 1980; Bjugstad and others 1981; Stevens and others 1981b; Rumbaugh and others 1982). In southern California, fourwing saltbush and quailbush (Atriplex lentiformis [Torr.] Wats.) have been established by seeding and transplanting to provide cover for upland game birds (California Department of Fish and Game 1968; McKibben and Slayback 1977).

To date, chenopod transplants have largely been produced in containers in greenhouses. Container seedlings of fourwing saltbush and other Atriplex species have been successfully propagated from seed or cuttings (Aldon 1970; Wiesner and Johnson 1977). Greenhouse propagation of winterfat has proven to be more difficult. Although the production of bareroot stock presents a number of problems, limited experience at the Lucky Peak Nursery, near Boise, Idaho, indicates that adequate stock of several species including fourwing saltbush, Gardner saltbush (Atriplex gardneri [Moq.] D. Dietr.), shadscale (A. confertifolia [Torr. & Frem.] Wats.), and winterfat may be produced at this site. Spiny hopsage (Grayia spinosa [Hook.] Moq.) and greasewood (Sarcobatus vermiculatus [Hook.] Torr.) seedlings have generally been of marginal quality. This paper will present an overview of problems and solutions associated with nursery propagation and outplanting of these species.

NURSERY PROPAGATION OF CHENOPOD SEEDLINGS

Seed

Named varieties of four chenopods have been released for commercial seed production by the U.S. Department of Agriculture, Soil Conservation Service, and cooperating agencies

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(table 1). Quality of seed produced under agricultural conditions should become superior to that of wildland collections as appropriate cultural practices are developed. Additional sources of seed include collections from selected populations grown at a nursery, collections from selected wildland stands, or purchases from commercial dealers. Seed transfer guidelines have not been established for chenopod species. For contract production, seed sources known to be adapted to the planting site must be obtained.

Seed must be carefully cleaned to obtain high purity levels, insure even flow through the drill, and maximize uniformity of seed placement and subsequent seedling development in the nursery bed. Purity of purchased seed may be adequate for rangeland seedings, but further cleaning may be required for nursery plantings. Seed produced in wildland stands frequently contains a high precentage of empty utricles, some of which can be removed by flotation or air separation. Fourwing saltbush, Gardner saltbush, greasewood, and spiny hopsage seeds are normally cleaned by hammermilling to remove appendages from the utricles (table 2) and fanning to remove trash. Although Springfield (1970) found that hammermilling fourwing saltbush fractures the utricle and improves germination, Smith and Martinez[1] determined that shadscale germination was not improved by this process. Booth (1983) reported that the fluffy hairs of winterfat utricles cling to the soil surface and guide the radicle into the soil. Hammermilling to separate the utricles from the seed and simplify seeding not only removed these hairs but frequently damaged the embryonic rootcap.

Optimum storage conditions and the effects of various storage regimes on seed quality and duration of seed viability have not been determined for most chenopods. Fourwing saltbush, shadscale, and Gardner saltbush seedlots have been safely stored under open, dry conditions for at least 5 years. Duration of viability, especially for Gardner saltbush, may vary widely among seedlots (Plummer and others 1968; Springfield 1968; Foiles 1974). Stevens and others (1981a) found seed of fourwing saltbush viable after 15 years of open, dry storage while winterfat seed viability declined rapidly after only 2 years. Springfield (1974b) succeeded in maintaining winterfat viability for 8 years by placing the seeds in cold, dry storage at 32° to 44° F (0° to 7° C).

Results of purity and germination or viability tests are used to provide an estimate of seed quality and are used in computing seeding rates. Purity and seed weights are obtained following standardized procedures (AOSA 1981). Association of Official Seed Analysts standards for testing the germination of chenopods and other native shrubs have not been established. Consequently, seed laboratories must develop or adopt procedures for each species. In addition, individual populations vary in germination requirements (Workman and West 1967; Clark and West 1971). As a result, tetrazolium chloride tests of seed viability are frequently substituted for germination tests. These tests are quickly completed and results are more consistent than those of germination tests.

Seed of most species matures in the fall (Plummer and others 1968; Eddleman 1977), and requires one to several months of afterripening in storage prior to planting (Springfield 1972; Foiles 1974). Although they vary greatly in size, seed of Atriplex species may be planted at rather precise spacings and depths with the Love-Oyjord or similar nursery drill. Seed is covered lightly with sand and may be mulched to improve moisture retention near the soil surface during germination and seedling emergence. Winterfat seed is not free flowing and cannot be metered through most drills. Seed is hand planted in shallow drill furrows or broadcast seeded on nursery beds formed with a roller or imprinter. Seed is covered by driving an imprinter over it. Winterfat seeds tend to cling together and cannot be effectively covered with a drag. Seed spacing has also been regulated by planting seeds encased in seed tapes.

Optimum seeding densities have not been established for nursery production. Estimates are based on experience with a limited number of seedlots. Fourwing saltbush and winterfat grow rapidly and are normally lifted as 1-0 stock (Ferguson and Monsen 1974). Target densities are 15 to 20 seedlings/ft^2 (161 to 215/m^2). Shadscale and Gardner saltbush grow more slowly and may be sown at higher densities (25 seedlings/ft^2 [269/m^2]). Depending on their growth rates, they may be lifted as 1-0 or 2-0 stock.

The amount of seed required to produce a requested number of seedlings may only be estimated. Culling rates and seedbed mortality figures have not been established at individual nursery sites as too few seedlots have been grown to provide adequate data. Although extreme variability occurs between seedlots, a seedbed mortality rate of 40 percent and culling rate of 20 percent are used in computing seeding rates at the Lucky Peak Nursery.

Nursery Practices

Cultural requirements have not been developed. Practices in use include a combination of propagation techniques used for conifers and hardwood trees and shrubs modified through onsite experience and observations and measurements of seedling development, growth rates, and morphological characteristics of individual species.

[1]Smith, B.; Martinez, E. S. Germination requirements and allelopathic characteristics of shadscale (Atriplex confertifolia). Unpublished draft provided to authors; 1983.

Table 1.--Chenopod cultivars cooperatively released by the U.S. Department of Agriculture, Soil Conservation Service[1].

Scientific name	Cultivar	Common name
Atriplex canescens	Rincon	Fourwing saltbush
Atriplex canescens	Marana	Fourwing saltbush
Atriplex canescens var. *aptera*	Wytana	Fourwing saltbush
Atriplex lentiformis	Casa	Quailbush
Atriplex semibaccata	Corto	Australian saltbush
Kochia prostrata	Immigrant	Forage kochia

[1]U.S. Department of Agriculture, Soil Conservation Service, 1982.

Table 2.--Propagation of chenopods as bareroot seedlings.

	Fourwing saltbush	Winterfat	Gardner saltbush	Shadscale	References
Seed collection dates	10/20-3/1	9/25-11/25	9/10-3/1	10/15-3/1	1
Seed cleaning	Dry, hammermill (1,500 rpm with 0.25-inch wire mesh), fanning mill.	Dry. Screen to remove twigs. Separate small debris with air blower.	Dry, fanning mill.	Dry, hammermill, fanning mill.	1, 2 3, 4, 5
Acceptable purity (percent)	95	50	90	95	1
Acceptable germination (percent)	50	85	45	35	1
Storage requirements	Open, dry, fumigate.	Open, dry or dry, cold (34°-42° F) in sealed containers.	Open, dry, fumigate.	Open, dry, fumigate.	1, 5 7, 8, 9
Duration of seed viability (years)	16+	0-3 (open storage) 8 (cold storage)	5	16+	2, 5, 6
Presowing treatment	10 months after-ripening.	9-13 weeks after-ripening.	3 months afterripening.	6-12 months afterripening.	5, 10, 11, 12, 18
No. seeds/pound cleaned seed	13,000-148,000	126,000-210,000	111,450	29,500-126,000	2, 5, 13
Seedbed mortality (percent)	40	40	40	40	14
Culling rate	20	20	20	20	14
Seedbed density (seedlings/ft^2)	15-20	15-20	25	25	14

Table 2.--(con.)

	Fourwing saltbush	Winterfat	Gardner saltbush	Shadscale	References
Sowing date	Fall, spring	Spring, (fall)	Fall, spring	Fall, spring	
Sowing method	Drill	Hand seed in drill furrows and cover lightly. Broadcast on firm surface. Cover lightly using imprinting implement.	Drill	Drill	
Sowing depth (inches)	0.50	<0.25	Near surface	0.50	5, 11, 15 16, 17, 19
Pruning:					
Top	Yes	No	No	No	
Root	Yes	No	No	No	
Lifting considerations	Brittle shoots, thick taproot, rigid lateral roots.	Woody shoots, thick taproot.	Woody branches decumbent at base.	Brittle shoots. Spinose branches. Thick taproot.	
Production period	1-0	1-0	1-0, 2-0	1-0, 2-0	14
Persistent leaves	Yes	Yes	Yes	Yes	
Vegetative propagation	Wildings, stem cuttings	Wildings	Wildings	Wildings	18
Special considerations	Seedlings susceptible to late frosts, damping off. Treat seed with fungicide.	Seedlings susceptible to late frost.	Seedlings susceptible to damping off. Treat seed with fungicides.	Erratic germination. Low growth rate.	3, 5

1. Jorgenson, K. R.; Stevens, R. Ephraim, UT: Data on file at Great Basin Experimental Area; 1982.
2. Plummer and others 1968.
3. Wasser 1982.
4. Booth 1983.
5. Foiles 1974.
6. Stevens and others 1981a.
7. Workman and West 1967.
8. Springfield 1974b.
9. Springfield 1968.
10. Springfield 1972.
11. Stevens and others 1977.
12. Springfield 1969.
13. Eddleman 1977.
14. Lucky Peak Nursery, Boise, ID: Data on file at Lucky Peak Nursery; 1975-1983.
15. Springfield 1974a.
16. Springfield 1971.
17. Nord and others 1971.
18. Wiesner and Johnson 1977.
19. Smith, B.; Martinez E. S. Germination requirements and allelopathic characteristics of shadscale (Atriplex confertifolia). Unpublished draft provided to authors; 1983.

Irrigation regimes have not been developed for individual species. Once established, arid land species require less irrigation than species from more mesic sites. However, logistics may prevent the use of specialized watering regimes for small seedling lots in the nursery. Throughout the germination period it is essential that the soil surface be kept moist. This is particularly important for winterfat and Gardner saltbush, which are sown near the soil surface, and for seedlots with low germination rates and long germination periods. This problem may be alleviated by mulching. Fourwing saltbush and Gardner saltbush are susceptible to damping off, particularly under cool, moist conditions. Seeds may be pretreated with Captan. If seedling mortality is noted, water should be applied only sparingly.

Soil fumigants may be applied to nursery beds prior to seeding to reduce weed problems, however, poor seed germination and erratic growth have been noted in midwestern nurseries when shrub species were seeded in fields fumigated with methyl bromide. Problems were attributed to decreased endomycorrhizal spores in the soil and endomycorrhizal development on seedlings (Riffle 1980). The use of fumigants such as Mylone that eliminate root pathogens, but are not harmful to mycorrhizal fungi, was recommended. Williams and others (1974) found growth of fourwing saltbush seedlings in the greenhouse to be enhanced by the presence of vesicular-arbuscular endomycorrhizae. Transplanting success has been improved by inoculating fourwing seedlings with Glomus mosseae Nicol. and Gerd. (Aldon 1975).

Most native shrub seedlings are weeded mechanically or by hand because herbicide recommendations are not available for individual species. Promising herbicide treatments must be tested on trial plots of individual species at the nursery site before large scale application is attempted (Sandquist and others 1981).

Chenopods are generally faster growing and less demanding of nutrients than conifers. Nitrogen applications are usually necessary, particularly if high carbon-nitrogen ratios develop as a result of mulching. Conifers and shrubs normally receive similar fertilizer treatments at the Lucky Peak Nursery. Two thousand pounds of 6-2-0 Milorganite (2 245 kg/ha) is incorporated into the soil prior to sowing. Ammonium nitrate (34-0-0) and superphosphate (0-46-0) are applied as side dressings.

Fourwing saltbush grows rapidly, producing a highly branched shoot during the first growing season. If germination occurs over a long period, large plants may dominate smaller or later germinating seedlings, reducing uniformity. Top-pruning larger seedlings encourages more uniform growth and improves shoot/root ratios by releasing smaller seedlings from competition. Seedlings may also be top or side pruned in the nursery during the dormant season or in the packing shed after lifting to provide a more desirable size and shape for packing and planting.

Roots are pruned to increase seedling uniformity, stimulate fibrous root development, and improve root/shoot ratios. Fourwing saltbush grows rapidly and produces an extensive root system during the first growing season. Excessively large root systems are produced when seedling densities are inadequate or germination occurs over a long period of time. Severing the taproot of fourwing saltbush serves to stimulate growth of lateral roots that are stronger and less easily damaged during lifting. Pruning taproots of rapidly growing species one or more times during the growing season at increasing depths (for example: 4, 6, and 8 inches (10, 15, and 20 cm) also prevents the development of a thick taproot at the normal lifting depth. Damage of thick, unpruned taproots during lifting leaves an open wound that is easily infected. Lateral root pruning is used to increase fibrous root development, control seedling size, and facilitate lifting.

Most chenopods are spring lifted prior to breaking dormancy. The stems and branches of many seedlings are rigid, brittle, and easily broken during lifting and packing and cannot be stored compactly. Fourwing saltbush and winterfat seedlings have been refrigerated in Kraft paper bags with polyethylene liners at 32° to 34° F (0° to 1° C) at the Lucky Peak Nursery for periods of 1 to 2 months before being planted.

OUTPLANTING

In southern Idaho, bareroot chenopod seedlings have been used in species adaptation trials and planting projects to enhance forage production and cover quality on arid rangelands adjacent to agricultural lands. Two outplantings will be described: (1) a test designed to aid in the development of grading criteria for fourwing saltbush seedlings and (2) an intertransplanting in a crested wheatgrass stand. Both trials were conducted within the Bell Rapids Study Area on the Snake River Plain in Twin Falls County, Idaho (see Shaw, Sands, and Turnipseed, this proceedings).

Fourwing Saltbush Seedling Grading Study

Fourwing saltbush bareroot seedlings grown at the Lucky Peak Nursery from a Sanpete County, Utah, seed source were lifted as 1-0 stock on March 9, 1982. Seedlings were grown at a nursery bed density of 10 per square foot ($108/m^2$) and were not root or top pruned. Lifted seedlings were graded into one of three size classes or a cull category based on the criteria listed in table 3. Thirty seedlings of each size class were handplanted at the Bell Rapids site on April 12, 1982. For each size class, 10 seedlings were planted in a randomly selected row within each of three blocks. Seedlings were planted on 8-foot (2.4-m) centers. The planting site was clean cultivated prior to planting, but a heavy cover of Russian thistle (Salsola kali L.) and

Table 3.--Comparison of three size classes of fourwing saltbush bareroot transplants after one growing season at the Bell Rapids study site, April 12, 1982 planting.

	Culls	Size class I	Size class II	Size class III
Grading criteria				
Shoot length (cm)	<5	5-10	10-20	>20
Root length (cm)	<30	30-35	30-35	>35 Taproot frequently severed
Caliper (root crown [mm])	<5.0	<5.0	5.0-7.5	>7.5
Percent of seedlings lifted	8	36	38	18
Growth performance[1]				
Survival (percent)		[2]37[a]	67[b]	13[a]
Height (cm)		12[a]	15[a]	22[a]
Crown (cm)		9[a]	9[a]	19[b]

[1]Seedlings were evaluated on October 12, 1982.

[2]Means followed by the same letter within rows are not significantly different ($P \leq 0.05$).

cheatgrass brome (Bromus tectorum L.) developed during the spring and summer. Survival, maximum seedling height, and maximum crown diameter measurements for each seedling were determined on October 12, 1982 (table 3). Results were tested by a one-way analysis of variance and the Duncan multiple range test (Steele and Torrie 1960).

Results--After one growing season, survival of intermediate (size class II) seedlings was significantly greater than that of the other two classes. Seedlings of the three size classes did not differ significantly in height, but crown diameters of the large size class (III) were significantly greater than those of the other two classes.

Grading criteria have not been developed for chenopod seedlings. McKell and Van Epps (1981) found plants with top growth consisting of several stems to be preferable to those with a single stem. Fourwing seedlings used in the present study had one main stem, but all had formed lateral branches. Results of this limited trial indicate that size class I seedlings may have had inadequate root and shoot development to establish and compete with other vegetation. Size class III seedlings had thick taproots, most of which were severed by undercutting prior to lifting. Lateral root development of these seedlings was very limited and the extensive lateral branching of the shoots caused the seedlings to be bulky and difficult to handle and plant. Results of this trial indicate that good survival can be obtained using healthy stock of adequate size even under semiarid conditions and amid competition. However, additional work is needed to better define plant characteristics which contribute to outplanting success and to determine whether root and top pruning treatments might improve survival.

Mechanical Transplanting

Seedlings of nine accessions of six shrub and forb species were intertransplanted into an established stand of crested wheatgrass on March 22, 1978. Planting stock included dormant 1-0 bareroot transplants of Wyoming big sagebrush (*Artemisia tridentata* Nutt. ssp. *wyomingensis* Beetle & Young), winterfat, Munro globemallow (*Sphaeralcea munroana* [Dougl.] Spach), and four accessions of fourwing saltbush (table 4). Dormant container seedlings of Nevada ephedra (*Ephedra nevadensis* Wats.) and Anderson peachbrush (*Prunus andersonii* A. Gray) grown in Leach tubes and hardened overwinter were also planted. Planting was accomplished by hand feeding the seedlings through a Forestland tree transplanter at 3- to 10-foot (0.9 to 3.0 m) spacings. The transplanter effectively cleared the crested wheatgrass from a furrow approximately 30 inches (76 cm) wide and 6 to 8 inches (15 to 20 cm) deep. Survival and maximum height and crown measurements of each shrub were recorded annually in late summer in 1978 and 1982.

Results--Survival of all fourwing saltbush, winterfat, and Wyoming big sagebrush accessions ranged from 77 to 100 percent following five growing seasons (table 4). Nearly all shrubs which did not survive succumbed during the first year. Nevada ephedra and Anderson peachbrush are not native to the area. Survival of these species declined during the first three growing seasons, but leveled off during the fourth year. Plants of both species have developed very slowly. Nevada ephedra is easily propagated in the nursery or greenhouse, but root and shoot systems of the seedlings are fragile and easily damaged during lifting or planting. Although survival of Munro globemallow has declined steadily, plants began flowering during the first growing season and the accession has spread from seed.

The furrow formed by the tree transplanter effectively released the shrubs from competition during the first two growing seasons. It did not become infested with weeds, but has slowly been reinvaded by crested wheatgrass. Van Epps and McKell (1983) obtained significantly higher survival for bareroot stock by controlling competition for 2 years.

Table 4.--Survival and growth of mechanically transplanted seedlings of nine accessions of six shrub and forb species after one and five growing seasons at the Bell Rapids Diagonal Tract, March 1978 planting.

Species	Source	Number planted	Year of evaluation	Survival	Height	Crown
				Percent	Mean (standard deviation)	
					--------*cm*---------	
Artemisia tridentata wyomingensis	Carey, Blaine Co., Idaho	150	1978	96	31(11)	14(5)
			1982	93	85(16)	73(22)
Atriplex canescens	Reynolds Creek, Owyhee Co., Idaho	103	1978	100	31(18)	74(17)
			1982	100	25(15)	116(41)
Atriplex canescens	Bliss, Gooding Co., Idaho	8	1978	100	33(19)	22(10)
			1982	100	72(15)	129(26)
Atriplex canescens	Nevada	81	1978	78	32(16)	20(11)
			1982	77	100(20)	161(48)
Atriplex canescens	New Mexico	108	1978	93	27(14)	18(10)
			1982	86	72(19)	123(46)
Ceratoides lanata	Hatch, Garfield Co., Utah	103	1978	97	24(13)	13(7)
			1982	93	67(15)	58(26)
Ephedra nevadensis	Wah Wah Valley, Beaver Co., Utah	107	1978	94	11(4)	11(4)
			1982	38	33(19)	21(13)
Prunus andersonii	Story Co., Nevada	52	1978	52	18(6)	10(4)
			1982	37	21(13)	13(9)
Sphaeralcea munroana	Boise, Ada Co., Idaho	101	1978	98	16(9)	19(11)
			1982	66	41(14)	53(27)

CONCLUSIONS

Nursery production records and outplanting trials indicate that seedlings of several chenopod species can be produced in a bareroot nursery and established on wildland sites. Seedlings may be used to stabilize disturbed areas and provide rapidly developing forage for livestock and big game and cover for birds and other small animals.

Chenopod seedlings in the nursery bed frequently vary in size and density as a result of typically low seed fill and erratic germination. Fourwing saltbush grows rapidly, producing a thick taproot and a densely branched shoot system. Pruning may be necessary to control plant size, improve shoot/root ratios, and facilitate handling. Shadscale and Gardner saltbush are slower growing and may be lifted as 1-0 or 2-0 stock depending upon growing conditions and seed source. The shoot systems of most seedlings tend to become woody, rigid, and sometimes brittle. This characteristic and the branching habits of fourwing and Gardner saltbush complicate handling, packing, and planting.

Results of an initial seedling grading trial indicate that best survival of fourwing saltbush transplants may be achieved using seedlings of an intermediate size class. Seedlings with shoots 4 to 8 inches (10 to 20 cm) in length and root systems which were not damaged during lifting demonstrated an ability to quickly become established and grow in dry areas.

Mechanical transplanting is a rapid means of planting large numbers of seedlings during short periods of favorable soil moisture. This technique may be used to remove competing grasses and transplant shrub seedlings within established crested wheatgrass stands. Reinvasion of crested wheatgrass into the furrow created by the transplanter occurred slowly and the incidence of annual weeds was minimal. Addition of shrubs to crested wheatgrass stands increases forage production and extends the period of grazing. Clusters of shrubs may be established by this technique to provide cover for upland game birds and other animals.

PUBLICATIONS CITED

Aldon, E. F. Fourwing saltbush can be field planted successfully. Res. Note RM-173. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1970. 2 p.

Aldon, E. F. Endomycorrhizae enhance survival and growth of fourwing saltbush on coal mine spoils. Res. Note RM-294. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1975. 2 p.

Aldon, E. F. Long-term plant survival and density from reclaimed southwestern coal mine spoils. Great Basin Naturalist. 4: 271-273; 1981.

Association of Official Seed Analysts. Rules for testing seeds. J. Seed Technology. 6: 1-126; 1981.

Bleak, A. T.; Frischknecht, N. C.; Plummer, A. P.; Eckert, R. E., Jr. Problems in artificial and natural revegetation of arid shadscale vegetation zone of Utah and Nevada. J. Range Manage. 18: 59-65; 1965.

Bjugstad, A. J.; Yamamoto, T.; Uresk, D. W. Shrub establishment on coal and bentonite clay mine spoils. In: Stelter, L. H.; DePuit, E. J.; Mikol, S. A., eds. Shrub establishment on disturbed arid and semi-arid lands; 1980 December 1-2; Laramie, WY. Cheyenne, WY: Wyoming Game and Fish Department; 1981: 138-154.

Booth, D. T. The ecological, physiological, and morphological effects of threshing winterfat fruits. In: Aldon, E. F.; Oaks, W. R. eds. Reclamation of mined lands in the southwest: a symposium; 1982 October 20-22; Albuquerque, NM. Albuquerque, NM: Soil Conservation Society of America; 1983: 133-137.

California Department of Fish and Game. *Atriplex*: a cover plant for wildlife. Game Management Leaflet No. 11. Sacramento, CA: California Department of Fish and Game; 1968. 11 p.

Clark, L. I.; West, N. E. Further studies of *Eurotia lanata* germination in relation to salinity. Southwest Naturalist. 15: 371-375; 1971.

DePuit, E. J. Coenenberg, J. G. Methods for establishment of native plant communities on topsoiled coal strip mine spoils in the Northern Great Plains. Reclam. Rev. 2: 75-88; 1979.

Eddleman, L. E. Indigenous plants of southeastern Montana. I. Viability and suitability for reclamation in the Fort Union Basin. Special Publ. 4. Missoula, MT: University of Montana, Montana Forestry and Conservation Experiment Station; 1977. 122 p.

Ferguson, R. B.; Frischknecht, N. C. Shrub establishment on reconstructed soils in semiarid areas. In: Stelter, L. H.; DePuit, E. J.; Mikol, S. A., eds. Shrub establishment on disturbed arid and semi-arid lands; 1980 December 1-2; Laramie, WY. Cheyenne, WY: Wyoming Game and Fish Department; 1981: 57-63.

Ferguson, R. B.; Monsen, S. B. Research with containerized shrubs and forbs in southern Idaho. In: Tinus, R. W.; Stein, W. I.; Balmer, W. E., eds. Proceedings of the North American containerized forest tree seedling symposium. Publ. 68. Denver, CO: Great Plains Agricultural Council; 1974. 458 p.

Foiles, M. W. Atriplex L., Saltbush. In: Shopmeyer, C. S., tech. coord. Seeds of woody plants in the United States. Agric. Hand. 450. Washington, DC: U.S. Department of Agriculture; 1974: 240-243.

Holmgren, R. C. The desert experimental range: description, history, and program. In: Hyder, D. N., ed. Arid shrublands - proceedings of the third workshop of the United States/Australia rangelands panel; 1973 March 26 - April 5; Tucson, AZ. Denver, CO: Society for Range Management; 1973: 18-23.

McKell, C. M.; Van Epps, G. A. Comparative results of shrub establishment in arid sites. In: Stelter, L. H.; DePuit, E. J.; Mikol, S. A., eds. Shrub establishment on disturbed arid and semi-arid lands; 1980 December 1-2; Laramie, WY. Cheyenne, WY: Wyoming Game and Fish Department; 1981: 138-154.

McKibben, L.; Slayback, R., compilers. Establishing woody plants for upland game habitat in California. Wildlife Habitat Leaflet 6. Sacramento, CA: California Department of Fish and Game, U.S. Department of Agriculture, Soil Conservation Service; 1977. 7 p.

McLean, A. The autecology of Atriplex nuttallii S. Wats. in southwestern Saskatchewan. Logan, UT: Utah State Agricultural College; 1953. 69 p. M.S. Thesis.

Monsen, S. B. Interseeding fourwing saltbush (Atriplex canescens [Pursh] Nutt.) with crested wheatgrass (Agropyron desertorum Schult.) on southern Idaho rangelands. In: Abstracts. Society for Range Management 33rd annual meeting. Denver, CO: Society for Range Management; 1980: 51.

Nord, E. C.; Hartless, P. F.; Nettleton, W. D. Effects of several factors on saltbush establishment in California. J. Range Manage. 24: 216-223; 1971.

Plummer, A. P.; Christensen, D. R.; Monsen, S. B. Restoring big-game range in Utah. Publ. 68-3. Salt Lake City, UT: Utah Department of Fish and Game; 1968. 183 p.

Riffle, J. W. Growth and endomycorrhizae development of broadleaf seedlings in fumigated nursery soil. For. Sci. 26: 403-413; 1980.

Rumbaugh, M. D,; Johnson, D. A.; Van Epps, G. A. Forage yield and quality in a Great Basin shrub, grass and legume pasture experiment. J. Range Manage. 35: 604-609; 1982.

Sandquist, R. E.; Owston, P. W.; McDonald, S. E. How to test herbicides at forest tree nurseries. Gen. Tech. Rep. PNW-127. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1981. 24 p.

Springfield, H. W. Cold storage helps winterfat seed retain viability. J. Range Manage. 21: 401-402; 1968.

Springfield, H. W. Temperatures for germination of fourwing saltbush. J. Range Manage. 22: 49-50; 1969.

Springfield, H. W. Germination and establishment of fourwing saltbush in the Southwest. Res. Pap. RM-55. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1970. 48 p.

Springfield, H. W. Winterfat seedlings emerge best from shallow seeding moderately dry soil. J. Range Manage. 24: 395-397; 1971.

Springfield, H. W. Winterfat seeds undergo after-ripening. J. Range Manage. 25: 479-480; 1972.

Springfield, H. W. Eurotia lanata (Pursh) Moq., Winterfat. In: Shopmeyer, C. S., tech. coord. Seeds of woody plants in the United States. Agric. Hand. 450. Washington, DC: U.S. Department of Agriculture; 1974a: 398-400.

Springfield, H. W. Winterfat seeds viable after eight years refrigerated storage. J. Range Manage. 27: 78; 1974b.

Stark, N. Review of highway planting information appropriate to Nevada. College of Agriculture Bulletin B-7. Reno, NV: University of Nevada, Desert Research Institute and Nevada State Highway Department; 1966. 209 p.

Steele, R. G. D.; Torrie, J. H. Principles and procedures of statistics. New York: McGraw-Hill; 1960.

Steger, R. E.; Beck, R. F. Range plants as ornamentals. J. Range Manage. 26: 72-74; 1973.

Stevens, R.; Giunta, B. C.; Jorgensen, K. R.; Plummer, A. P. Winterfat (Ceratoides lanata). Publ. 77-2. Salt Lake City, UT: Utah Division of Wildlife Resources; 1977. 41 p.

Stevens, R.; Jorgensen, K. R.; Davis, J. N. Viability of seed from thirty-two shrub and forb species through fifteen years of warehouse storage. Great Basin Naturalist. 41: 274-277; 1981a.

Stevens, R.; Moden, W. L., Jr.; McKenzie, D. W. Interseeding and transplanting shrubs and forbs into grass communities. Rangelands. 3: 55-58; 1981b.

U.S. Department of Agriculture, Soil Conservation Service. Improved plant materials. Tech. Note 42. Washington, DC: U.S. Department of Agriculture, Soil Conservation Service; 1982. 17 p.

Van Epps, G. A.; McKell, C. M. Effect of weedy annuals on the survival and growth of transplants under arid conditions. J. Range Manage. 36: 366-369; 1983.

Wasser, C. H. Ecology and culture of selected species useful in revegetating disturbed lands in the West. Washington, DC: U.S. Department of Interior, Office of Biological Services, Fish and Wildlife Service; 1982. 347 p.

Wiesner, L. E.; Johnson, W. J. Fourwing saltbush (*Atriplex canescens*) propagation techniques. J. Range Manage. 30: 154-156; 1977.

Williams, S. E.; Wollums, A. G., II; Aldon, E. F. Growth of *Atriplex canescens* (Pursh) Nutt. improved by formation of vescicular-arbuscular mycorrhizae. Soil Sci. Soc. Am. Proc. 38: 962-965; 1974.

Workman, J. P.; West, N. E. Germination of *Eurotia lanata* in relation to temperature and salinity. Ecology. 48: 659-661; 1967.

In: Tiedemann, Arthur R.; McArthur, E. Durant; Stutz, Howard C.; Stevens, Richard; Johnson, Kendall L., compilers. Proceedings--symposium on the biology of *Atriplex* and related chenopods; 1983 May 2-6; Provo, UT. General Technical Report INT-172. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 309 p.

PROPAGATION OF FOURWING SALTBUSH (ATRIPLEX CANESCENS [PURSH] NUTT.)

BY STEM CUTTINGS

E. Durant McArthur, A. Clyde Blauer, and Gary L. Noller

ABSTRACT: A technique that describes rooting of fourwing saltbush (Atriplex canescens [Pursh] Nutt.) stems is given. In general, nonterminal vegetative branches work best. Rooted cuttings can be produced under favorable circumstances as quickly as 10-14 days. Male plants, for some accessions at least, root better and more quickly than female plants.

INTRODUCTION

Rooted cuttings of fourwing saltbush (Atriplex canescens [Pursh] Nutt.) are needed to establish seed orchards and other plantations where the gender and position of plants are important. Fourwing saltbush is subdioecious with at least three genders (McArthur and Freeman 1982). Moreover, rooted cuttings can be used to propagate superior individual plants for a variety of purposes including breeding programs and provision of superior or uniform outplanting stock (Everett and others 1978; McArthur and others 1978; Richardson and others 1979).

Atriplex canescens is an attractive candidate for propagation by vegetative cuttings because some of its populations (Woodmansee and Potter 1970; Stutz and others 1975) and related species (Nord and others 1969) are known to reproduce by vegetative means. In fact, several researchers have successfully rooted stems of fourwing saltbush and other Atriplex species (Nord and Goodin 1970; Wieland and others 1971; Ellern 1972; Wiesner and Johnson 1977; Everett and others 1978; Richardson and others 1979). However, the previously described methods were generally performed on small sample sizes, on few populations, were not specifically designed for fourwing saltbush, or required several weeks for successful rooting. In the course of our studies we found we could have high success in a short (2-week) period. This paper reports our technique.

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MATERIALS AND METHODS

Stem sections of current and prior years' growth were taken from several naturally occurring populations (table 1) and from plantations of 'Rincon' fourwing saltbush[1] (table 2). If it was necessary to store plant material before processing, the branches were stored in an ice chest or coldroom. Cuttings were taken year round. Our cutting technique is more similar to that of Richardson and others (1979) than other published techniques.

Table 1.--Rooting of cuttings from natural populations of fourwing saltbush.

Population	Chromosome number	Gender	Number of plants	Number of plants with 50% > rooted cuttings
Little Sahara Sand Dunes, Juab Co., Utah	2x	female	11	11
		male	11	11
Kingston Canyon, Paiute Co., Utah	4x	female	17	14
		male	11	10
		monoecious	12	10
Rincon Blanco, Rio Arriba Co., New Mexico	4x	female	3	3
		male	3	3
		monoecious	3	3
Spanish Fork, Utah Co., Utah	4x	female	12	11
		male	11	11
		monoecious	10	9
Grantsville, Tooele Co., Utah	6x	female	8	6
		male	11	11
		monoecious	7	4
TOTALS			130	117

[1]McArthur, E. D.; Stranathan, S. E.; Noller, G. L. 'Rincon' fourwing saltbush--proven for better forage and reclamation. Unpublished article in press at Rangelands.

Table 2.--Rooting of 'Rincon' fourwing saltbush cuttings.

Year[1]	Gender	Number of plants	Number of ramets	Success: Number of plants > 50 percent	Success: $\bar{x}$, Percent of all ramets
1978	female	22	1,592	8	38.1
	male	25	1,656	8	37.0
	monoecious	33	1,893	1	16.2
	all	80	5,141	19	29.6
1979	female	22	3,156	12	76.6
	male	10	620	10	84.2
	monoecious	4	256	4	89.8
	all	36	4,032	16	78.5
1982	female	6	1,084	NA	42.7
	male	4	465	NA	68.2
	all	10	1,549		50.8

[1]The 1978 work was accomplished at the Snow Field Station, Ephraim, Utah; the 1979 work at the Shrub Sciences Laboratory, Provo, Utah; and the 1982 work at the Upper Colorado Environmental Plant Center, Meeker, Colorado. Mechanical failures of misting and air conditioning systems lowered the success for 1978 and 1982.

To make the cuttings, the tops of the stem sections, including the upper leaves with the stems, were cut straight across with a sharp razor blade. The bottom of the stem section was cut sharply at a 45° angle. The lower inch and a half (3.8 cm) of the stem was stripped of leaves and branches. Large drooping, upper leaves were also removed. This was done in an attempt to reduce wilting and to avoid leaf contact with the planting media (peat pellets). Cuttings that had two or three upper nodes with leaves, branches, or both, remaining after the lower ones were removed were generally selected for rooting. Long stems produced several cuttings.

After this initial preparation, the cuttings were placed in a 20-20-20 (nitrogen-phosphate-potash) fertilizer solution (30 g/gal or 7.9 g/liter) for at least 1 hour. As the cuttings were removed from the solution, they were dipped in "Rootone F" rooting hormone powder, and inserted into moisted "Jiffy-7 (703)" peat pellets. W. R. Oaks[2] reports success with concentrated growth regulators and no fertilizer soak.

The cuttings were then placed on a mist bench either on plastic trays with drain holes or on beds of perlite. In the summer (May-October) the misting regime was one or two 30-second bursts every half hour from 6 a.m. to 5 p.m. From 5 p.m. to 6 a.m. the 30-second bursts were given every 45 minutes. Our system had a 10-minute mist-activator clock which was controlled in turn by a 24-hour clock by 15-minute intervals. From November to April the misting system was considerably drier--7 to 15 seconds each hour and a half. Mist room temperature was maintained at 60° to 70° F (16° to 21° C).

[2]Oaks, W. R. Personal communication with authors, 1983.

After roots were visible outside the peat pellets, the cuttings were placed in a pre-dampened potting medium in 4- by 4- by 4-inch pots (10.2- by 10.2- by 10.2-cm). The potting medium consisted of five parts peat, three parts vermiculite, and two parts sand with amendments (table 3). The plants were then grown to size and maintained in greenhouses or lathhouses, depending upon season.

Table 3.--Fertilizer amendments added to 3.4-ft^3 (0.9-m^3) potting medium.

Amendment	Quantity
	grams
Dolomitic limestone	555
Agricultural limestone	75
Calcium nitrate	81
Phosphate	63
Osmocote	108
FTE[1]	9
Sesquestrene-138	3
Gypsum	252

[1]Frittered trace elements (manganese, iron, copper, zinc, boron, molybdenum).

RESULTS AND DISCUSSION

We found, as did Richardson and others (1979), that fourwing saltbush cuttings could be rooted best in the summer. Our success was over 90 percent for some plants during July. The 10,000 cuttings reported in table 2 are a fraction of the number of cuttings we have produced. The results for 1979 (table 2), which were from

cuttings all collected in July or August, illustrate the high success rates attainable using our methods. Plants root much more rapidly in the summer. In central Utah, cuttings made in July and August would routinely be ready for transplanting in 3 weeks. In January, 6 weeks were required to develop roots.

In general, succulent current year's growth beginning at the annual growth scar proved to root most readily. We recommend that one to three segments 2.5 to 5 inches (6.4 to 12.7 cm) long from current year's vegetative branches be used. Freshly cut branches are best, but we have had success with branches stored at about 35° F (2° C) up to 5 days. We have also had success with woody branches and floral branches. Nevertheless we recommend nonterminal portions of current year vegetative branches. Some natural populations (table 1) did not have a sufficient number of the "ideal" succulent vegetative branches for propagation and the "nonideal" branches did produce some roots. The method has been demonstrated successfully on several morphological forms, chromosome races, and genders (table 1). Individual plants in populations have been reported to vary in the amount of roots they will produce (Everett and others 1978; Richardson and others 1979). Our experience has been that some roots are produced by almost any plant, but some populations and plants root much more profusely than others (table 1).

Our results, taken in total (tables 1 and 2), do not prove different rooting responses of the genders. Richardson and others (1979) drew this conclusion. However, the 1982 sample does have a highly significantly (DF=1; $X^2=84.3$, $p << 0.01$) different rooting response between male and female cuttings. McArthur[3] has data that show that rooted male cuttings have much more rapid early growth than do monoecious and female cuttings. Results of our present experiments (fig. 1) show that male 'Rincon' fourwing saltbush cuttings root more rapidly than females.

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[3]McArthur, E. D. Provo, UT: Data on file at Shrub Sciences Laboratory; 1983.

Figure 1.--Week after cutting that roots appeared by gender. Data collected in 1982 at Upper Colorado Plant Materials Center on cuttings made during the first week of August.

PUBLICATIONS CITED

Ellern, S. J. Root cuttings of saltbush (Atriplex halimus L.). J. Range Manage. 25: 154-155; 1972.

Everett, R. L.; Meeuwig, R. O.; Robertson, J. H. Propagation of Nevada shrubs by stem cuttings. J. Range Manage. 31: 426-429; 1978.

McArthur, E. D.; Freeman, D. C. Sex expression in Atriplex canescens: genetics and environment. Bot. Gaz. 143: 476-482; 1982.

McArthur, E. D.; Plummer, A. P.; Van Epps, G. A.; Freeman, D. C.; Jorgensen, K. R. Producing fourwing saltbush seed in seed orchards. In: Hyder, D. N., ed. Proceedings, first international rangeland congress; 1978 August 14-18; Denver, CO. Denver, CO: Society for Range Management; 1978: 406-410.

Nord, E. D.; Christensen, D. R.; Plummer, A. P. Atriplex species (or taxa) that spread by root sprouts, stem layers, and by seed. Ecology. 50: 324-326; 1969.

Nord, E. C.; Goodin, J. R. Root cuttings of shrub species for planting in California wildlands. Res. Note PSW-213. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1970. 3 p.

Richardson, S. G.; Barker, J. R.; Crofts, K. A.; Van Epps, G. A. Factors affecting root of stem cuttings of salt desert shrubs. J. Range Manage. 32: 280-283; 1979.

Stutz, H. D.; Melby, J. M.; Livingston, G. K. Evolutionary studies of Atriplex: a relict gigas diploid population of Atriplex canescens. Am. J. Bot. 62: 236-245; 1975.

Wieland, P. A. T.; Frolich, E. F.; Wallace, A. Vegetative propagation of woody shrub species from the northern Mojave and southern Great Basin deserts. Madrono 21: 149-152; 1971.

Wiesner, L. E.; Johnson, W. J. Fourwing saltbush (Atriplex canescens) propagation techniques. J. Range Manage. 30: 154-156; 1977.

Woodmansee, R. G.; Potter, L. D. Vegetative reproduction of fourwing saltbush in New Mexico. J. Range Manage. 23: 371; 1970.

In: Tiedemann, Arthur R.; McArthur, E. Durant; Stutz, Howard C.; Stevens, Richard; Johnson, Kendall L., compilers. Proceedings--symposium on the biology of Atriplex and related chenopods; 1983 May 2-6; Provo, UT. General Technical Report INT-172. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 309 p.

METHODS FOR ESTABLISHING FOURWING SALTBUSH (Atriplex canescens [Pursh]Nutt.) ON DISTURBED SITES IN THE SOUTHWEST

Earl F. Aldon

ABSTRACT: This paper outlines: (1) the techniques for establishing fourwing saltbush (Atriplex canescens [Pursh]Nutt.) on disturbed sites using transplants, (2) methods needed for establishing this plant on surface coal mine areas by direct seeding and with supplemental irrigation, and (3) the long-term survival of fourwing saltbush on reclaimed coal mine spoils.

INTRODUCTION

Fourwing saltbush (Atriplex canescens [Pursh] Nutt.), an excellent soil stablizer, is a nutritious all-season forage plant for grazing animals; it provides food and cover for wildlife and traps sediment on alluvial flood plains. A 20-year watershed rehabilitation project has concentrated research on the establishment of this plant on disturbed areas in the Southwest (Aldon 1973). In the course of these studies, the requirements for growing seedlings and successfully transplanting these plants on disturbed sites have been worked out and are listed in this paper.

In addition, research has been conducted on methods for direct seeding of fourwing saltbush on areas disturbed by the surface mining of coal in the Southwest (Aldon 1975). Fourwing transplants have also been used, with and without supplemental irrigation, to establish these shrubs on raw mine spoil. These findings as well as the long-term survival of these plantings are included here.

LITERATURE REVIEW

Many workers have tested methods for growing this desirable plant under field conditions. Cassady and Glendening (1940), working in the Southwest, thought transplanting fourwing saltbush seedlings during the rainy season was best. Plummer and others (1966) reported seedlings, nursery stock, or wildlings could be transplanted easily early in the spring. Burnham and Johnson (1950), however, reported results of their attempts to transplant seedlings to the field in northeastern New Mexico were poor.

Springfield (1970) found the growth of transplants in New Mexico differed according to source of seed and thought seed should be obtained from nearby or north of the planting site. Aldon (1976) found similar results in New Mexico. Springfield (1970) tried 1-year-old bare-root stock grown at the Soil Conservation Service (SCS) Los Lunas Plant Materials Center and found survival best when soil moisture was near field capacity, temperatures were cool at the time of planting, and grass competition was eliminated. Plummer and others (1966) found 16- to 20-week-old container grown seedlings were especially successful in field plantings in Utah. Springfield (1970) found survival of transplants exceeded 50 percent after 3 years at all sites if seedlings were at least 8 weeks old and 6 inches (15.2 cm) high. Direct seeding has also been tried. Hervey (1955) reported spring seedings were more successful than fall seedings in Colorado. Plummer and others (1966) obtained the best stands from winter planting; seeds were broadcast on snow and covered by chaining in late winter or early spring. Springfield (1970) thought seedbed preparation probably was necessary to obtain good stands of fourwing saltbush by direct seeding. Plowing was the best method of seedbed preparation where the native cover was composed mainly of undesirable plants. Spring and midsummer seedings were more successful than fall seedings in the Southwest. Success of seeding depended largely on the amount and seasonal distribution of precipitation during the period when temperatures were favorable for germination and establishment. Control of rabbits and rodents, where they are numerous, was recommended.

GROWING TRANSPLANTS (Aldon 1970a)

1. Collect seeds from plants growing near the site where planting is contemplated. Gather seeds in late October or early November, after they are mature and dry, but before they fall. Seeds are a light brown color at this time. SCS cultivars may also be used if they have wide adaptability.

2. Store over winter in open plastic bags in a dry place at room temperature. Special storage conditions are not necessary (Springfield 1968). Refrigeration does not improve seed viability.

3. In early April, remove wings from

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seeds and select 100 seeds at random. Cut them in half and count the filled and hollow seeds. Filled seeds usually are viable (capable of germinating). Compute the number of seeds needed so that about four will germinate in each planting container.

4. Mix thoroughly two-thirds good garden soil with one-third soil taken from under a fourwing saltbush plant and place in 2- by 2-inch (51- by 51-cm) wide and 3-inch (76-cm) deep heavy-weight felt paper plant bands.

Line bottom of flats with heavy plastic. These containers pack tightly and hold up well in field transplanting. This soil mix is necessary to inoculate the plant with growth-stimulating micro-organisms.

5. Place enough seeds on the surface to produce about four seedlings and cover with one-fourth inch (7 mm) of the soil mix. Planting should start sometime between mid-April and mid-May when outdoor temperatures are optimum, between 55^{o} and 75^{o} F (12^{o}-22^{o} C). Seeds began germinating within 3 days at 65^{o} to 73^{o} F (19^{o}-21^{o} C).

6. Water daily with a fine mist to keep the surface moist. Heavy watering will float seeds out of the soil. Keep the bands where the sun will hit them for several hours a day. When plants are one-half inch (14 mm) tall, they can be flooded from the top when needed.

7. When plants are about 3 weeks old, thin to one per band. Remove grasses and weeds from the bands as they appear.

FIELD PLANTING (Aldon 1970b)

1. Plant in areas that will be flooded periodically but not inundated more than 30 hours. In the Southwest, it is important to wait until the probability for sizable (>0.40 inch; >10 mm) summer thunderstorms exceeds 50 percent, generally in late July or early August. Soil moisture stress should be less than 2 atmospheres of tension (Aldon 1972). For alluvial bottomlands, this is about 13 percent soil moisture.

2. Seedlings should be planted before 10 a.m. to minimize stresses. Plants should be shaded or covered and watered well while being transported to the planting site.

3. Make a 4-inch (11-cm) deep hole, insert plant band, and damp soil around it. The band top should be at ground level, not below. Roots apparently need not be laid straight down. They can be bent, but should not be broken.

4. Plant with 5-foot (1.5-m) spacings. It is unreasonable to expect greater plant densities through revegetation than would be found on undisturbed sites. In favorable years, plants can grow 2 feet (62 cm) tall the first year.

5. Cover transplanted seedlings with straw to minimize stresses and reduce frost heaving that may occur the first winter. Spray straw mulch and fourwing saltbush plants with 1:1 mixture of water and animal repellent.

SEEDLING PLANTING ON THE MCKINLEY COAL MINE

The McKinley, 20 miles northwest of Gallup, operates in the Gallup Mesaverde coal field. The climate is semiarid. Annual precipitation averages 10 to 14 inches (20.5-36 cm), a third of which falls as high-intensity rains in July and August. Another third falls as snow from December through March. Dry, windy weather prevails during the spring; less than 1.5 inch (38 mm) of precipitation falls from April to June. Elevation ranges from 6,800 to 7,300 feet (2,000-2,200 m). Temperatures reach extremes of -35^{o} to 95^{o} F (-38^{o} to 35^{o} C). Pinyon (*Pinus edulis* Engelm.)-juniper (*Juniperus monosperma* [Engelm.] Sarg.) is the dominant vegetation, occupying the plateaus, benches, mesas, rocky breaks, and steeper slopes. Associated with the trees are several shrubs, such as mountain-mahogany (*Cercocarpus montanus* Raf.) and cliffrose (*Cowania mexicana* D. Don), and a sparse herbaceous understory, including squirreltail (*Sitanion hystrix* [Nutt.] J.G. Sm.). The relatively narrow valleys filled with moderately deep alluvium support big sagebush (*Artemesia tridentata* Nutt.) with an understory mainly of western wheatgrass (*Agropyron smithii* Rydb.) and blue grama (*Bouteloua gracilis* [H.B.K.] Steud.).

In August 1973, 50 seedlings of fourwing saltbush were transplanted at the mine. All seedlings were grown in asphalt-impregnated, paper plant bands which were removed before transplanting. The seedlings were transplanted with soil intact, and were watered in. The transplants were 3-month-old stock. The plot was fenced initially to exclude livestock and game, but fence integrity, at least against rabbits and small rodents, was not maintained. No additional water was provided.

Initial survival was checked in November 1973, and in October or November of 1974, 1978, and 1979.

In November 1973, 80 percent were alive and by October 1979, 67 percent of the seedlings had survived. The fourwing saltbush plants are vigorous, averaging between 2 and 3 feet (62-90 cm) in height, and about 2 feet (62 cm) in diameter. The plants were spreading by seedlings. Progeny seedlings were vigorous and well-established (Aldon and Pase 1981). Precipitation was average over the period.

STUDIES AT THE NAVAJO MINE

The Navajo Mine is located near Farmington, N. Mex., in the Four Corners area of the United States.

The area surrounding the study area is rangeland with a scattering of low-growing shrubs. Principal grasses include galleta (Hilaria jamesii [Torr.] Benth.), alkali sacaton (Sporobolus airoides [Torr.] Torr.), and Indian ricegrass (Oryzopsis hymenoides [R. & S.] Ricker). Shadscale (Atriplex confertifolia [Torr. & Frem.] Wats.), fourwing saltbush, and broadscale (Atriplex obovata Moq.) are the most important shrub species. At higher elevations, pinyon and juniper trees are found scattered on mesa tops. Elevation ranges from 5,000 to 6,500 feet (1,524-2,000 m). Annual precipitation averages only 6 to 8 inches (15-20 cm). Summer is usually wetter than winter; spring and fall are the drier seasons. Temperature extremes range from -25° to 115° F (-32° to 44° C).

The plantings were on untreated spoil material (no topsoil used) from the Watson Pit area of the Navajo Mine. The spoil is a dark, shale-derived material having the following characteristics:

Sand, percent	31
Silt, percent	27
Clay, percent	42
Textural class	clay
Sodium absorption ration (SAR)	44
Electrical conductivity x 10^3	15
pH	7.7

Direct Seeding Trials

Fourwing saltbush was direct-seeded at the Navajo Mine on a low-lying area in March 1973. The area had a wet winter and early spring, so residual soil moisture was good; about two times normal precipitation had fallen. Seeds were planted when temperatures were optimum--62° F (16° C) daytime and cold nights. Seeds were hand broadcast over the area and covered by raking. No supplemental watering was done. In May, about 400 plants had germinated. By September 1973, over half of the plants had survived. Two years later, survival was 15 percent and plants averaged 32.4 inches (80 cm) in height and 29.8 inches (73 cm) in diameter. About 64 percent are male plants and 36 percent female plants (Aldon 1975).

Five years after establishment, 62 percent of the previously established plants were alive and averaged 2.3 feet (72.4 cm) in height and 1.8 feet (55.4 cm) in diameter. The plants were 14 percent shorter and 27 percent narrower than they had been 5 years earlier probably due to plant competition. No grazing was present during this time. After some mortality a plant now occupies about 30 ft^2 (2.9 m^2), whereas a mature plant occupied about 20 ft^2 (1.8 m^2) 2 years after planting. Precipitation was average over the period (Aldon 1981).

Drip Irrigation Tests

Drip irrigation is a method which allows water to drip slowly from small emitters along a pipe. Two 100-foot (30-m) lengths of 1/2-inch (13-mm) plastic pipe were laid about 20 feet (6 m) apart on graded spoil material at the Navajo mine. Emitters were located at 1-foot (0.3-m) intervals along 60 feet (18 m) of each line. Each line was connected to a water source. Three-month-old transplants of fourwing saltbush, grown by techniques outlined above, were planted alternately at each emitter. Ten transplants of each species, used as controls, were planted between the lines but not watered.

Seedlings were transplanted in mid-September 1973, and watered twice a week (eight times) until the first hard frost. Discharge rates under gravity feed were 1.4 gallons (5.3 liters) per emitter per hour. Each emitter delivered about 4 gallons (15 liters) per watering. Plants were not watered after the first growing season.

Drip irrigation significantly improved survival though planting was late in the season. Height, diameter, and size index (height diameter) were also significantly better. This benefit was still apparent 22 months after planting (Aldon 1975).

Long-term survival of fourwing saltbush on these irrigated plots was 88 percent. Average plant height went from 2 feet (62 cm) in 1975 to 2.8 feet (85.3 cm) in 1979; average plant diameter went from 1.9 to 3.2 feet (59.7 cm to 98.3 cm). Each plant now occupies about 23 ft^2 (2.23 m^2). Plant size and spacing seem to be related. Closely spaced plants were smaller and had large die-offs compared to plants that were more widely spaced initially (Aldon 1981).

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PUBLICATIONS CITED

Aldon, Earl F. Growing fourwing saltbush transplants for field planting. Res. Note RM-161. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1970a. 3 p.

Aldon, Earl F. Fourwing saltbush can be field planted successfully. Res. Note RM-173. Fort Collins, CO; U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1970b. 2 p.

Aldon, Earl F. Critical soil moisture levels for field planting fourwing saltbush. J. Range Manage. 25:311-312; 1972.

Aldon, Earl F. Revegetating disturbed areas in the semi-arid Southwest. J. Soil and Water Conserv. 28(5):223-225; 1973.

Aldon, Earl F. Techniques for establishing native plants on coal mine spoils in New Mexico. In: Third symposium on surface mining and reclamation: National Coal Association/Bituminious Coal Association Coal Conference and Expo II; 1975 October; Louisville, KY. Washington, DC: National Coal Association 1975: 21-28. Vol. 1.

Aldon, Earl F. Seed sources, species selection and current research on species adaptation for mine spoil reclamation. In: Vories, Kimery C., ed. reclamation of western surface mined lands: workshop proceedings 1976 March 1-3, Fort Collins, CO. Ecology Consultants Inc.; 1976: 99-101.

Aldon, Earl F. Long-term plant survival and density data from reclaimed southwestern coal mine spoils. Great Basin Naturalist. 41(3): 271-273; 1981.

Aldon, Earl F.; Pase, Charles P. Plant species adaptability on mine spoils in the Southwest: a case study. Res. Note RM-398. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1981. 3 p.

Burnham, D. R.; Johnson, E. W. Shrubs for northeastern New Mexico. Bull 358. Las Cruces, NM: New Mexico Agricultural Experiment Station; 1950. 28 p.

Cassady, J. T.; Glendening, G. E. Revegetating semidesert range lands in the Southwest. Forestry Publ. 8. Washington, DC: U.S. Civilian Conservation Corps; 1940. 22 p.

Hervey, Donald F. Factors which influence the reseeding of certain browse species in Colorado. College Station, TX: A and M College of Texas; 1955. 109 p. (Ph.D. dissertation.)

Plummer, A. Perry; Monsen, Stephen B.; Christensen, Donald R. Fourwing saltbush a shrub for future game ranges. Publ. 66-4. Salt Lake City, UT: Utah State Department Fish and Game; 1966. 12 p.

Springfield, H. W. Cold storage not required for fourwing saltbush seeds. J. Range Manage. 21:335-336; 1968.

Springfield, H. W. Germination and establishment of fourwing saltbush in the Southwest. Res. Pap. RM-55. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1970. 48 p.

In: Tiedemann, Arthur R.; McArthur, E. Durant; Stutz, Howard C.; Stevens, Richard; Johnson, Kendall L., compilers. Proceedings--symposium on the biology of Atriplex and related chenopods; 1983 May 2-6; Provo, UT. General Technical Report INT-172. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 309 p.

SEEDING TECHNIQUES TO IMPROVE ESTABLISHMENT OF FORAGE KOCHIA

(KOCHIA PROSTRATA [L.] SCHRAD.) AND FOURWING

SALTBUSH (ATRIPLEX CANESCENS [PURSH] NUTT.)

Richard Stevens and Gordon A. Van Epps

ABSTRACT: Seeding trials were conducted to determine the effects seeding techniques, mulching, and seed cleaning techniques have on seedling emergence. The largest number of forage kochia (Kochia prostrata [L.] Schrad.) seedlings occurred when seed was not covered at seeding time. Mulching did not increase the number of emerged seedlings. Mulching increased the number of fourwing saltbush (Atriplex canescens [Pursh] Nutt.) seedlings. Utricle size and the absence or presence of utricle wings did not affect seedling numbers. Significantly more fourwing saltbush seedlings emerged when utricles were covered at seeding.

INTRODUCTION

Forage kochia (Kochia prostrata [L.] Schrad.) is a low-growing (under 35 inches [89 cm] perennial chenopod shrub introduced to North America from southern Eurasia (Keller and Bleak 1974). This shrub shows promise of being an important forage producer and soil stabilizer on arid western ranges (Blauer and others 1976). Important characteristics exhibited by forage kochia in the Intermountain West are: fairly high salt tolerance (Francois 1976; McArthur and others 1978), drought tolerance (Larin 1956; Balyan 1972: Keller and Bleak 1974; McArthur and others 1974 and 1978; Moghaddam 1978; Aldon and Pase 1981; Romo and others 1984), adaptability to cold (-15°F [-26°C]) and hot (115°F [46°C]) climates (Blauer and others 1976; McArthur and others 1978; Aldon and Pase 1981), low oxalate levels (Britton and Sneva 1977; Williams 1977; Davis 1979), ability to spread rapidly from seed (McArthur and others 1974; Frischknecht and Ferguson 1979), rapid and high seed production (Balyan 1972; McArthur and others 1974), semi-evergreen habitat (Balyan 1972), good protein content throughout the year (Akhmetov 1970; Moghaddam 1976 and 1978; Otsyina and McKell 1984; Otsyina and others, this proceedings), good palatability to livestock and big game (Larin 1956; Balyan 1972; Blauer and others 1976; Nemati 1977; Otsyina and McKell 1984; Welch and Davis[1]), provision of food and cover to upland game birds (Stevens[2]), compatibility with other perennials (Stevens[2]), competitive with annuals (Stevens[2]), and some fire tolerance (Stevens[2]).

Establishment of forage kochia by direct seeding has been sporadic (Young and others 1981; Romo and Haferkamp 1984; Stevens[2]). Problems with retention of seed viability could have some effect on sporadic establishment (Waller and others 1979; Jorgensen and Davis, this proceedings). Reproduction from established stands has filled in interspaces. Natural spread has occurred in the direction of the prevailing winds at over 30 sites in Utah. Experience has demonstrated that the most productive results from direct seedings were obtained when seeds were not covered. Similar results were obtained with K. scoparia [L.] Schrad. (Everett and others 1983). An Agricultural Research Service report (USDA 1961) recommends that seed be drilled to 0.2 inches (0.5 cm) deep. Forage kochia has been established in Halogeton glomeratus C.A. Mey. in Ledeb. communities when seed was broadcast into the stands with no seed covering. Likewise, forage kochia has been established in cheatgrass brome (Bromus tectorum L.) stands by broadcast seeding on disturbed seedbeds (Stevens[2]).

Similarly, results have been sporadic with fourwing saltbush (Atriplex canescens [Pursh] Nutt.). Consistently good stands (350-450 plants/acre [140-180/ha]) have not been obtained in many rangeland seeding projects. A standard seeding procedure is to seed dewinged utricles 0.25 to 0.5 inch (0.6 cm to 1.2 cm) deep. Because of the importance and potential of fourwing saltbush in range improvement, this study also included that species to try to find ways of improving stand establishment. This study was implemented to determine the effects of various types of seed covering, dewinging, and mulching on seedling emergence.

METHODS

Seed trials were conducted at the Nephi Dryland Field Station near Nephi, central Utah. Soils are a clay loam. Annual precipitation during the study year (1980-81) was 14.7 inches (37 cm). The field had been summer fallowed for 2 years: the soil surface was slightly crusted with considerable cracking.

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[1]Welch, B. L.; Davis, J. N. In Vitro digestability of Kochia prostrata. Great Basin Naturalist, In press.

[2]Stevens, R. Data on file, Great Basin Experiment Station; Ephraim, Utah.

New seed of forage kochia grown at Snow Field Station, Ephraim, Utah, originating from Russia (P.I. 314929), and fresh fourwing saltbush seed collected east of Ephraim were used. Forage kochia seed was cleaned to over 95 percent purity (seed was considered clean with the bracts on). Fourwing saltbush utricles were divided into two size groups, large (when dewinged, utricle diameter greater than 0.125 inch [0.3 cm]) and small (less than 0.125 inch). One half of each size class was dewinged in a hammermill. One half of the dewinged seed was cleaned to 96 percent purity; the second half was not cleaned. Utricles with wings were cleaned to 99 percent purity. Mulch material consisted of cropped bitterbrush (*Purshia tridentata* [Pursh] DC.) limbs.

Site preparation and seeding occurred on January 27, 1981. Number of seedlings was counted the following spring and summer (May 29 and July 16). Plots were 4.9 feet (1.5 m) square. One thousand seeds were seeded into each plot. Treatments were replicated four times in a split plot design.

Seed treatments were: (a) forage kochia seed cleaned to 95 percent purity, and (b) fourwing saltbush seed with six different treatments: (1) large utricles with wings, (2) large utricles dewinged and cleaned, (3) large utricles dewinged and uncleaned, (4) small utricles with wings, (5) small utricles dewinged and cleaned, and (6) small utricles dewinged and uncleaned.

Soil treatments were: (1) broadcasting seed onto undisturbed soil, (2) disturbing the soil and broadcasting seed into it, (3) disturbing the soil, broadcasting the seed, followed by additional soil disturbance, and (4) broadcasting seed and then disturbing the soil. Soil disturbance consisted of dragging a garden rake with 1.33 inch (3.9 cm) tines through the plot twice.

Mulch treatments were: (1) cropped bitterbrush limbs, 1 inch (2.54 cm) deep, and (2) no mulch.

Seed of forage kochia were broadcast seeded into each soil treatment with and without a mulch covering. Seed from the six different fourwing saltbush treatments were broadcast seeded into each of the soil treatments, with and without a mulch covering.

Data were subjected to analysis of variance, and Newman-Kuels multiple range test (Woolfe 1968) to detect difference among the treatment means.

RESULTS AND DISCUSSION

Forage Kochia

Forage kochia germination occurred in early March, resulting in no significant difference in the number of seedlings between May 29 and July 16. The absence or presence of mulch did not significantly affect the number of seedlings. The plots (table 1) that were seeded and then disturbed (treatments 3 and 4) had the fewest number of seedlings. The largest number of seedlings occurred where seed was broadcast onto undisturbed soil (treatment 1). The most successful field and test plot plantings resulted when seed of forage kochia was intentionally or purposely scattered on the soil surface. The results of this study indicate that seed of forage kochia should not be covered after seeding.

Table 1.--Mean number of forage kochia seedlings in 1.5 m square plots resulting from four different seeding techniques.

Treatments	Mean number of seedlings per plot
1- Seed on soil surface	[1]16.4
2- Disturbed soil - seed	14.4
3- Disturbed soil - seed - disturbed soil	13.6
4- Seed - disturbed soil	9.1

[1]Values connected by the same line are not significantly different at the 1 percent level.

Fourwing Saltbush

Fourwing saltbush seed germinated later than forage kochia seed. There were significantly more seedlings on July 16 than on May 29 (table 2), indicating a considerable amount of germination occurrred in June and early July.

Fourwing saltbush seedlings are somewhat susceptible to frost (Plummer and others 1966). Mulching resulted in significantly more seedlings than were present on nonmulched plots (table 2). Mulch could

Table 2.--Mean number of fourwing saltbush seedlings in 1.5 m square plots on two dates and with various seeding techniques.

Item	Mean number of seedlings per plot
Treatment date	
May 29	0.3
July 16	1.0
Utricle size	
Small	[1]0.7
Large	0.5
Seed treatment	
With wings on	0.6
Dewinged - uncleaned	0.7
Dewinged - cleaned	0.6
Mulch	
No mulch	0.5
With mulch	0.8
Soil treatment	
Seed on soil surface	0.1
Disturbed soil - seed	0.4
Disturbed soil - seed - disturbed soil	1.0
Seed - disturbed soil	1.0

[1]Values connected by the same line are not significantly different at the 1 percent level.

protect seedlings from frost and other damaging climatic factors.

Utricle size did not have an effect on the number of seedlings that emerged; neither did dewinging or cleaning (table 2). Utricles are commonly dewinged for ease of handling and seeding; however, this treatment evidently does not reduce or enhance seedling emergence.

SUMMARY

Forage kochia, a potentially important shrub on western ranges, is an early spring germinator. The most successful seeding occurred when seed of forage kochia was broadcast seeded and not covered. Mulching did not enhance the number of seedlings.

Covering fourwing saltbush utricles resulted in the greatest number of seedlings. Mulching increased seedling numbers. There was no difference in the number of seedlings that emerged from winged and dewinged utricles. Utricle size did not affect the number of seedlings.

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PUBLICATIONS CITED

Aldon, E. F.; Pase, C. P. Plant species adaptability on mine spoils, in the southwest: a case study. Res. Note RM 398. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1981. 3 p.

Balyan, G. A. Prostrate summer cypress and its culture in Kirghizia. Frunze, USSR: Isdatel, stovo "Kyrgyztan"; 1972. 296 p. (translated 1979, U.S. Department of Commerce, RR77-59026).

Blauer, A. C.; Plummer, A. P.; McArthur, E. D.; Stevens, R.; Guinta, B. C. Characteristics and hybridization of important Intermountain shrubs II. Chenopod family. Res. Pap. INT-77. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1976. 42 p.

Britton, C. M.; Sneva, F. A. Production and chemical attributes of Kochia prostrata. In: Abstracts of papers: 30th annual meeting, Society for Range Management; 1977; Portland, OR. Denver, CO: Society for Range Management; 1977: 12.

Davis, A. M. Forage quality of prostrate kochia compared with three browse species. Agron. J. 71: 822-824; 1979.

Everett, H. H.; Alanix, M. A.; Lee, J. B. Seed germination characteristics of Kochia scoparia. J. Range Manage. 36: 646-648; 1983.

Francois, L. E. Salt tolerance of prostrate summer cypress (Kochia prostrata). Agron. J. 68: 455-456; 1976.

Frischknecht, N. C.; Ferguson, R. B. Revegetating processed oil shale and coal spoils on semi-arid lands. Interim Report EPA 600/7-79-068. Washington DC: U.S. Environmental Protection Agency; 1979. 47 p.

Golovchenko, S.; Akhmetov, K. The best time to cut Kochia prostrata for hay. Luga Pastbishcha. 6: 40; 1970.

Keller, W.; Bleak, A. T, Kochia prostrata: a shrub for western ranges? Utah Science. 35: 24-25; 1974.

Larin, I. V. Pasture economy and meadow cultivation. Leningrad, USSR; 1976. Translated 1962, National Science Foundation, Washington DC; by the Israel Program for Scientific Translations, Jerusalem.

McArthur, E. D.; Guinta, B. C.; Plummer, A. P. Shrubs for restoration of depleted ranges and disturbed areas. Utah Science. 35: 28-33; 1974.

McArthur, E. D.; Plummer, A. P.; Davis, J. N. Rehabilitation of game range in the salt desert. In: Johnson, K. L., ed. Wyoming shrublands, proceedings, 7th Wyoming shrub ecology workshop. Laramie, WY: University of Wyoming; 1978: 23-50. 58 p.

Moghaddam, M. R. Kochia prostrata: a shrub for arid lands. In: Abstracts of papers: 29th annual meeting, Society for Range Management; 1976; Omaha, Neb. Denver, CO: Society for Range Management; 1976: 53 p.

Moghaddam, M. R. Kochia prostrata: a plant material for range improvement in arid and semi-arid regions. J. Range Manage. 5: 153-154; 1978.

Nemati, N. Comparative palatability of Atriplex canescens. J. Range Manage. 5: 153-154; 1978.

Otsyina, R. M.; McKell, C. M. Potential of Kochia prostrata as a forage complement for grass pasture in fall. In: Abstracts of papers: 37th annual meeting, Society for Range Management; 1984; Rapid City, SD. Denver, CO: Society for Range Management; 1984: 173.

Plummer, A. P.; Monsen, S. B.; Christensen, D. R. Fourwing saltbush a shrub for future game ranges. Pub. 66-4. Salt Lake City, UT: Utah Department of Fish and Game; 1966. 12 p.

Romo, J. T.; Hafterkamp, M. R. Kochia prostrata germination response to water stress and specific ions. In: Abstracts of papers: 37th annual meeting, Society for Range Management; 1984; Rapid City, SD. Denver, CO: Society for Range Management; 1984: 258.

Romo, J. T.; Haferkamp, M. R.; Miller, R. F. Temperal variation in water relations of Kochia prostrata. In: Abstracts of papers: 37th annual meeting, Society for Range Management; 1984; Rapid City, SD. Denver, CO: Society for Range Management; 1984: 282.

U. S. Department of Agriculture, Agriculture Research Service. Livestock in the Soviet Union. Washington, DC: U.S. Department of Agriculture, Agricultural Research Service: Report of Technical Study Group; 1961.

Waller, S. S.; Schmidt, K. K.; Stubbendieck, J. L.; Britton, C. M.; Sneva, F. A. Effect of harvest date and drying procedures on germination of *Kochia prostrata* (L.) Schrad. In: 1979 Progress report: Research in rangeland management. Special Report 549. Corvallis, OR: Oregon State University Agricultural Experiment Station; 1979; 8-10.

Williams, M. C. Poisonous plant newsletter, USDA-SEA, Poisonous Plant Research Lab. Logan, UT: Spring 1977. 11 p.

Woolfe, C. M. Principles of biometry. Princeton, NJ: D. Van Nostrand Company; 1968. 359 p.

Young, J. A.; Evans, R. A.; Stevens, R.; Everett, R. L. Germination of *Kochia prostrata* seed. Agron J. 73: 957-961; 1981.

In: Tiedemann, Arthur R.; McArthur, E. Durant; Stutz, Howard C.; Stevens, Richard; Johnson, Kendall L., compilers. Proceedings--symposium on the biology of *Atriplex* and related chenopods; 1983 May 2-6; Provo, UT. General Technical Report INT-172. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 309 p.

DEVELOPMENT OF 'RINCON' FOURWING SALTBUSH, WINTERFAT, AND OTHER SHRUBS FROM SEED FOLLOWING FIRE

Warren P. Clary and Arthur R. Tiedemann

ABSTRACT: Seeding trials consisting of a shrub mix and a shrub-grass mix were established on a recent burn in central Utah. Shrubs included winterfat, 'Rincon' fourwing saltbush, Hobble Creek Vasey big sagebrush, and antelope bitterbrush. Shrub-grass mixes included, in addition to these species, 'Ephraim' crested wheatgrass, 'Paiute' drought-tolerant orchardgrass, Bozoisky Russian wildrye, and 'Magnar' basin wildrye. One-half of the plots were fertilized. Mean total shrub establishment ranged from 1,726 to 8,452 plants per acre (4 263 to 20 876/ha). Average winterfat and 'Rincon' fourwing saltbush establishment was 4,200 per acre (10 374/ha) and 1,400 per acre (3 458/ha). Fertilization significantly enhanced recruitment of big sagebrush. Shrub recruitment was reduced when grasses were seeded with shrubs, but was more strongly inhibited by residual native perennial grasses.

INTRODUCTION

Rehabilitation of rangelands by seeding began in the western United States in the late 1800's. More literature exists on range seeding than any other practice in range management (Heady 1975). As might be expected, there is a long history of impressive successes and disappointing failures.

Numerous factors affect seeding success and should be considered in seeding prescriptions (Plummer and others 1968). Matching the plant species to the climate and soil conditions is a major item. Although general agreement exists that species mixes are better than single species, little information is available on the performance of individual species in a mixture. The shrub, grass, and forb composition of a seed mix affects composition of the resultant plant community, but other factors, including competition, growth rate, drought tolerance, and climatic parameters, ultimately influence plant expression (Doerr and others 1983). Because of these variables, it may not be possible to predict the community that will result from a given mix of species.

Initial soil fertility may also be important, but apparently little or no work has been done in the Intermountain region on the possible benefits of starter fertilizer. Such fertilizers were essential for successful plant establishment in north-central Washington (Klock and others 1975). Nitrogen fertilizer applied to established plant stands has greatly increased production of crested wheatgrass (*Agropyron desertorum* Fisch.), but its effect on native vegetation has varied from modest to none (West and Skujins 1978). Recently, Doerr and others (1983) studied the effect of fertilization on biomass and cover of seeded shrubs, grasses, and forbs in a big sagebrush (*Artemisia tridentata* Nutt.)/western wheatgrass (*Agropyron smithii* Rydb.) area in Colorado. Fertilization significantly increased biomass of shrubs and grasses during the first season following seeding, but there was no significant response by seeded forbs. During the following 2 years, differences in biomass between fertilized and nonfertilized shrubs and grasses diminished to nonsignificance. Fertilization most benefited shrubs deprived of supplemental irrigation. Canopy cover was then two times greater on fertilized plots.

Lightning-caused wildfires in late July 1981 burned over 62,000 acres (25 100 ha) on the Oak Creek range study area in Millard and Juab Counties, central Utah. The Little Oak Creek fire burned across Forest Service, Bureau of Land Management, State, and private land--mostly in the big sagebrush (*Artemisia tridentata* Nutt.)/pinyon (*Pinus edulis* Engelm.)-juniper (*Juniperus scopulorum* Sarg.) zone. The fire was quite hot, resulting in several thousand hectares with virtually no debris and an exceptionally clean seedbed for attempts at revegetation. In December 1981, we established a study on this burn to compare revegetation success of several combinations of plant materials and a starter fertilizer.

The information in this paper is based on the first 2 years' observations from two seeding

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and fertilization treatments, and will focus on the performance of shrub species in relation to development of native and seeded grasses. One seeding treatment was a mixture of shrubs including the newly released 'Rincon' fourwing saltbush (McArthur and others 1982). The other was a mixture of grasses and shrubs including the newly released 'Paiute' drought-tolerant orchardgrass and 'Ephraim' rhizomatous crested wheatgrass varieties (Stevens and others 1983a and 1983b). The starter fertilizer treatment consisted of fertilization versus no fertilization.

METHODS

The study is near the center of the Little Oak Creek burn 30 miles (48 km) south of Nephi, Utah. The experiment utilized a randomized block design. Four blocks (study areas) were established to span an elevation gradient between 5,080 ft (1 540 m) and 5,520 ft (1 671 m) within the limits of the big sagebrush vegetation zone. The lowest area is near a greasewood (*Sarcobatus vermiculatus* [Hook.] Torr.) bottomland. The upper area is in the lower portion of a big sagebrush/pinyon-juniper ecotone. Within each block, 11 treatments were applied.

Four of these treatments were evaluated for this paper; a shrub seed mixture and shrub-grass seed mixture, each applied under fertilized and unfertilized conditions. The shrub materials were 'Rincon' fourwing saltbush (*Atriplex canescens* [Pursh] Nutt.), Hobble Creek[1] Vasey big sagebrush (*Artemisia tridentata* Nutt. var. *vaseyana*), winterfat (*Ceratoides lanata* [Pursh] Moq.), and antelope bitterbrush (*Purshia tridentata* [Pursh] DC). The shrub-grass mixture included the mentioned shrubs and the grasses Bozoisky[2] Russian wildrye (*Elymus junceus* Fisch.), 'Paiute' drought-tolerant orchardgrass (*Dactylis glomerata* L.), 'Ephraim' rhizomatous crested wheatgrass (*Agropyron cristatum* [L.] Gaertn.), and 'Magnar' basin wildrye (*Elymus cinereus* Scribn. & Merr.).

The blocks were seeded in early December 1981. The 33- by 33-ft (10- by 10-m) plots were prepared by pulling a straight-tooth harrow behind a small tractor. Consumption of vegetation and litter by fire was complete and no additional seedbed preparation was considered necessary. Seed and fertilizer were broadcast and covered by dragging a light chain across each plot. All seed mixes were applied at the rate of 40 pure live seed (PLS) per ft^2 (430/m^2). On the shrub-only plots, each of the four species was planted at the rate of 10 PLS per ft^2 (108/m^2). In the shrub-grass plots, each of the eight species was applied at the rate of 5 seeds per ft^2 (54/m^2). Fertilizer was applied as 16-20-0-8, nitrogen (N), phosphorus (P), potassium (K), sulfur (S) to provide nitrogen at the rate of 50 lb per acre (56 kg/ha). On the fertilized plots on study areas 3 and 4, our treatments (especially the shrub-only treatment) were confounded by accidental aerial application of seed during the post-fire revegetation effort (table 1).

Sampling of the vegetation was conducted in April and August 1983. The total number of shrubs was counted at both times within each treatment. Only height measurements were made in April. Shrub height and average crown diameter measurements were made in August on the first 20 individuals encountered per species per treatment. Shrub height and crown diameter were used to

[1] Hobble Creek is not a varietal release name. It refers to the area of origin of the seed near Springville, Utah.

[2] Bozoisky is not a varietal release name; it refers to the area of origin in Russia.

Table 1.--Species and rates seeded aerially during post-fire revegetation efforts.

Species	Rate lb/acre	Rate kg/ha
'Fairway' crested wheatgrass (*Agropyron cristatum* [L.] Gaertn.)	3.0	3.4
Intermediate wheatgrass (*Agropyron intermedium* [Host] Beauv.)	1.5	1.7
'Luna' pubescent wheatgrass (*A. intermedium* var. *trichophorum* [Link] Halacsy)	1.0	1.1
Russian wildrye	1.5	1.7
'Ladak' alfalfa (*Medicago sativa* L.)	1.5	1.7
Small burnet (*Sanguisorba minor* Scop.)	1.0	1.1
Yellow sweetclover (*Melilotus officinalis* [L.] Pallas)	.25	.28
'Manchar' smooth brome (*Bromus inermis* Leyss.)	.25	.28

develop shrub volume estimates. Perennial herbaceous plant cover was sampled within each treatment in three randomly located 0.3- by 6-m belt transects. Cover, expressed as a percentage of soil surface covered by projection of foliar material onto the ground, was recorded for each seeded and native plant species present, within 20 contiguous plots in each belt transect. Seeded plant densities on the contiguous plots were also recorded. Where differences among treatments were significant according to the F-test, the Tukey procedure was used for mean comparisons (Steel and Torrie 1960).

In August, only study areas 2, 3, and 4 were measured. Study area 1 had such a heavy growth of annual plants that evaluation of seeded species was not feasible (fig. 1).

RESULTS AND DISCUSSION

Immediately after the fire, conditions for plant establishment appeared to be similar across the burned area. However, after the first growing season, major differences were apparent (fig. 1). Seedlings in study area 1 (near a greasewood bottom) were subjected to intense competition by annual plants such as bur buttercup (Ranunculus testiculatus Crantz), tumblemustard (Sisymbrium altissimum L.), pepperweed (Lepidium perfoliatum L.), cheatgrass brome (Bromus tectorum L.), Russian thistle (Salsola

Area 1

Area 2

Area 3

Area 4

Figure 1.--Views of study areas, August 1983.

iberica Sennen & Pau), and halogeton (Halogeton glomeratus C.A. Mey.). Study area 2 was subjected to periodic severe wind erosion for approximately 1 year after seeding. This resulted in the loss of 2 to 3 inches (5 to 8 cm) of topsoil, as measured from stumps of big sagebrush plants which had been burned to ground level. Nearly all the introduced and native seed was likely blown away. The surface of area 2 remained largely devoid of plant growth 2 years after the fire. Study areas 3 and 4 contained substantial residual native bunchgrasses--principally bluebunch wheatgrass (Agropyron spicatum [Pursh] Scribn. & Sm.) and were inadvertently seeded during post-fire revegetation efforts on the remainder of the burn (table 1).

Winterfat was the most successful shrub in terms of number of plants established (table 2). The recruitment of winterfat seedlings in April was nearly 1 percent of the number of seed planted. This significantly exceeded the success of the other three shrubs. Hobble Creek big sagebrush and 'Rincon' fourwing saltbush recruitment were 0.38 percent and 0.24 percent, respectively. Antelope bitterbrush with only a 0.04 percent recruitment, was far less successful than the other shrubs. The pattern of recruitment in August was similar to April with one exception: density of antelope bitterbrush seedlings had increased. Differences were not significant among the sagebrush, fourwing saltbush, and bitterbrush recruitments.

Table 2.--Average recruitment of shrub seedlings by species as a percent of planted seed.

	April[1]	August[2]
Winterfat	[3]0.82[a]	0.75[a]
Hobble Creek Vasey big sagebrush	.38[b]	.32[b]
'Rincon' fourwing saltbush	.24[b]	.18[b]
Antelope bitterbrush	.04[c]	.12[b]

[1]Data from study areas 1-4.

[2]Data from study areas 2, 3, and 4.

[3]Values in the same column followed by different letters are significantly different at $P < 0.05$.

The change in apparent recruitment between April and August was tested by comparing plant counts in study areas 2, 3, and 4. Area 1 was excluded from the April evaluation because values would have distorted the apparent change in recruitment and invalidate the comparison with August.

There was no significant change in mean recruitment from April to August for fourwing saltbush, significant decreases for winterfat and big sagebrush, but a significant increase for antelope bitterbrush (table 3). Antelope bitterbrush may have delayed seed germination or may develop more slowly to a 'findable' size than the other shrub species.

Fertilization significantly enhanced recruitment of big sagebrush on the shrub-only plots but had no effect on the other shrub species. Big sagebrush recruitment was doubled by fertilization on the April sample date and more than doubled by August. This result indicates that fertilization should be considered as a means of improving plant recruitment when seeding big sagebrush.

Shrub recruitment was not improved by fertilization on the shrub-grass plots.

Competition from perennial grasses tended to reduce recruitment of all four shrub species but big sagebrush was the only individual species for which the differences were statistically significant. On the shrub-grass/ fertilized treatment, big sagebrush recruitment was reduced by eight and 15 times for April and August, respectively, compared to the shrub/fertilized treatment.

Considerable grass competition was present even in plots where only shrub establishment had been intended. As a result of the inadvertent aerial seeding on areas 3 and 4, there was over 2 percent cover of seeded perennial grasses on shrub-only plots (table 4). Residual native perennial grasses on these plots provided approximately the same cover. Our seeding treatment more than doubled cover of seeded perennial grasses. Surprisingly, cover of native perennial grasses was nearly twice as great on shrub-grass as shrub-only plots. Apparently, the random shrub-grass plots within study areas 3 and 4 coincided with areas of greatest residual perennial grass cover.

Initially we expected that seeded grass species would present the most severe competition or resistance to establishment of seedling shrubs because the grass varieties had been selected for their ability to develop rapidly and for their hardiness under arid or semi-arid conditions. There was a great deal of variability in shrub recruitment between study areas 3 and 4, apparently unrelated to establishment of seeded grass species. Also, very few annual plants were present on areas 2, 3, or 4, so this was not a factor.

Table 3.--Comparative shrub recruitment in April and August on study sites 2, 3, and 4 expressed as percent of PLS applied.

	Fourwing saltbush		Winterfat		Big sagebrush		Antelope bitterbrush	
Treatment	April	August	April	August	April	August	April	August
Shrub/fertilized	[1]0.22[a]	0.31[a]	1.25[a]	1.00[a]	0.85[a]	0.76[a]	0.04[a]	0.08[a]
Shrub/not fertilized	.22[a]	.27[a]	1.02[a]	.90[a]	.43[b]	.33[b]	.08[a]	.22[a]
Shrub-grass/fertilized	.10[a]	.07[a]	.79[a]	.55[a]	.11[b]	.05[b]	.01[a]	.06[a]
Shrub-grass/not fertilized	.02[a]	.05[a]	.73[a]	.58[a]	.17[b]	.13[b]	.06[a]	.11[a]
MEAN	[2].14[A]	.18[A]	.95[A]	.76[B]	.39[A]	.32[B]	.05[A]	.12[B]
	NS		*		*		*	

[1] Values followed by the same lower case letter are not significantly different from other values in the same column at P < 0.05.

[2] Values followed by the same upper case letter are not significantly different between April and August for individual species at P < 0.05.

Table 4.--Percent cover of perennial herbaceous plants in study areas 2, 3, and 4.

	Shrub fertilized	Shrub not fertilized	Shrub-grass fertilized	Shrub-grass not fertilized
Seeded perennial grasses	2.28	2.25	5.83	4.33
Native perennial grasses	2.50	1.98	4.37	3.32
Perennial forbs	.65	1.22	.37	1.78
Total	5.43	5.45	10.57	9.43

Recruitment variability was, however, related primarily to the cover of native perennial bunchgrasses (fig. 2). These bunchgrasses, predominantly bluebunch wheatgrass, are not generally considered to be extremely competitive plants. However, they were well established in study areas 3 and 4 at the time of the fire and provided strong competition to emerging shrub seedlings early in the first growing season at a time when the seeded grasses were also just emerging. Seeded grasses may prove to be more competitive to shrubs in later years, but the natives surviving the fire appear to be the most effective competitors during initial seedling establishment. Our results were comparable to those of Blaisdell (1949). He found that good stands of perennial grasses often prevented establishment of sagebrush seedlings.

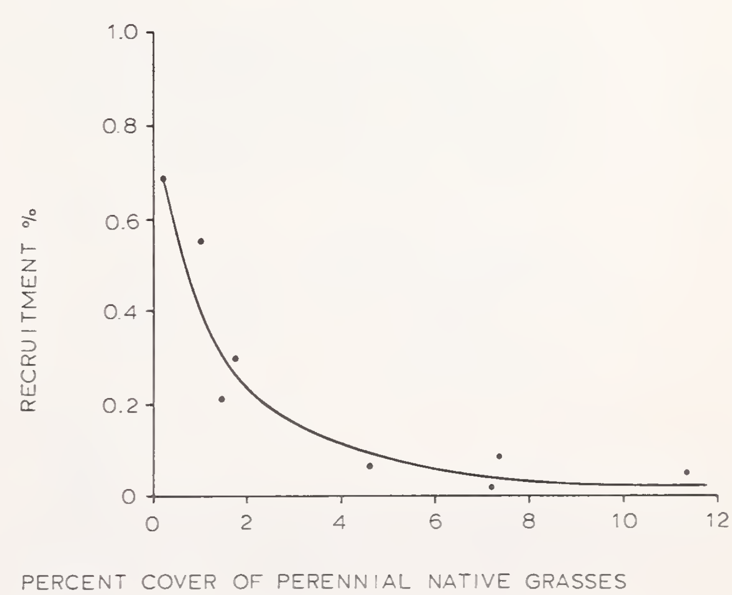

Figure 2.--Relationship of shrub recruitment to cover of native perennial grasses on study areas 3 and 4.

A native bunchgrass cover of only 1 percent in area 4 (as compared to 8 percent in area 3), few annuals, and no noticeable soil loss resulted in the best shrub recruitment (table 5). Land managers should carefully scrutinize the potential success of shrub establishment relative to the costs of seeding shrubs after fire in areas with adequate stands of perennial grasses.

Table 5.--Average shrub seedling recruitment on the four study areas in decreasing order.

Area	Elevation	April	August
	ft	---percent---	
Area 4 Juniper-sagebrush ecotone	5,520	[1]0.94[a]	0.88[a]
Area 1 Lower sagebrush zone	5,080	.33[b]	--
Area 3 Upper sagebrush zone	5,500	.18[bc]	.10[b]
Area 2 Mid sagebrush zone	5,280	.02[c]	.05[b]

[1]Areas followed by different letters are significantly different at $P < 0.05$ within the same month.

Although 'adequate' is a qualitative term that needs clarification in terms of density and cover, it is a relationship that needs to be developed if we are to make sound prescriptions for revegetating areas in the future.

The actual densities of shrub seedlings illustrate the greater success of shrub seedling establishment where fewer grasses were present. The shrub-only plots had about four times the shrub seedlings as the shrub-grass plots even though the seeding rate was only twice as heavy (table 6). In addition, net seedling reduction was considerably greater through the second growing season in the shrub-grass plots.

No guidelines exist delineating the number of shrubs needed to constitute a successful seeding. For a large stature shrub such as 'Rincon' with a crown spread of approximately 6 ft (1.2 m), 500 plants per acre (1 235/ha) would provide 32 percent canopy coverage or one-third of the site occupied. We suggest this would represent an acceptable level of establishment. This was achieved with shrub-only treatments but not with the shrub-grass. For smaller statured plants such as winterfat with a crown spread of about 18 inches (0.5 m), 32 percent cover would require approximately 7,800 plants per acre (19 260/ha). This level was not achieved with any treatment.

'Rincon' fourwing saltbush seedlings were significantly taller and produced the greatest crown volume per plot (number X height X width^2) of any shrub species (table 7). The average 'Rincon' fourwing

Table 6.--Densities per acre of shrub seedlings.

Species	Shrub mix		Shrub-grass mix	
	April[1]	August[2]	April	August
Winterfat	4,244	4,080	1,456	1,220
Hobble Creek big sagebrush	2,580	2,347	344	200
'Rincon' fourwing saltbush	1,436	1,260	340	133
Antelope bitterbrush	192	660	60	173
Total	8,452	8,347	2,200	1,726
Percent mortality	1		22	

[1] Areas 1-4.

[2] Areas 2-4.

saltbush at the end of the second growing season produced 20 times the crown volume of the average winterfat, and about 40 times the crown volume of Hobble Creek big sagebrush. Study area number 2 with a few very large 'Rincon' plants had five times the shrub crown volume of area 4, and 16 times the volume of area 3. These areas supported more small winterfat and sagebrush plants.

Table 7.--Height and crown volume of the shrub seedlings.

Species	Height	Volume
	inches	ft^3
'Rincon' fourwing saltbush	[1]10.9[a]	2.0[a]
Winterfat	6.9[b]	.7[b]
Antelope bitterbrush	5.6[b]	.1[b]
Hobble Creek big sagebrush	3.0[b]	.1[b]

[1]Species followed by different letters are significantly different at $P < 0.05$.

SUMMARY AND CONCLUSIONS

Four study areas were utilized in a seeding and fertilizer study on a large wildfire burn which occurred in July 1981. The treatments were applied in December 1981. All four study areas were read in April 1983; areas 2, 3, and 4 were read in August 1983.

Establishment conditions for seeded species appeared difficult in three of the four study areas. Area 1 had severe competition from annual plants; area 2 had extreme wind-caused soil erosion (and associated seed loss); and area 3 had substantial native perennial bunchgrasses. Establishment conditions for shrubs were best in area 4 with few annuals, no noticeable soil loss, and only moderate cover of native bunchgrasses.

General conclusions are:

1. Total shrub recruitment was less than 1 percent of the PLS applied but resultant densities of all shrubs ranged from 1,726 per acre to 8,452 per acre (4 263/ha to 20 876/ha). Occupancy ranged from 1 shrub per 25 ft^2 (1/5.8 m^2) to 1 shrub per 5 ft^2 (1/1.2 m^2) and indicates a high level of seeding success.

2. Results suggest that seeding shrubs only at a rate of 5-10 PLS per square foot would result in an average of more than 4,000 plants per acre (9 880/ha) of winterfat and more than 1,200 plants per acre (2 964/ha) of 'Rincon' fourwing saltbush.

3. Average winterfat establishment was highest of all shrubs, but its relative advantage was greatest on the higher elevation plots.

4. 'Rincon' fourwing saltbush was intermediate in establishment success. Its highest recruitment occurred in study area 1 which was near a greasewood bottom.

5. Starter fertilizer treatments are promising; apparently enhancing recruitment in the shrub-only plots, but not in the shrub-grass plots. Big sagebrush recruitment was enhanced more (two to two and one-half times) by fertilization than that of any other shrub species.

6. Difference in recruitment between the April and August evaluations of the second growing season was not significantly different for 'Rincon' fourwing saltbush, but decreased significantly for winterfat.

7. Recruitment of shrub seedlings as a percentage of seed planted was greater where there were less seeded grasses.

8. Residual native perennial bunchgrasses exerted a strong negative influence on shrub seedling establishment and shrub cover development.

9. Land managers should carefully scrutinize the potential success of shrub establishment relative to the cost of seeding shrubs in areas with well developed stands of perennial grasses.

10. Shrub crown volume was greatest on plots with a few large fourwing saltbush seedlings; less on those plots with a large number of winterfat and big sagebrush seedlings.

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PUBLICATIONS CITED

Blaisdell, J. P. Competition between sagebrush seedlings and reseeded grasses. Ecology 30: 512-519; 1949.

Doerr, T. B.; Redente, E. F.; Sievers, T. E. Effect of cultural practices on seeded plant communities on intensively disturbed soils. J. Range Manage. 36: 423-428; 1983.

Heady, H. F. Rangeland management. New York: McGraw-Hill; 1975. 460 p.

Klock, G. O.; Tiedemann, A. R.; Lopushinsky, W. Seeding recommendations for disturbed mountain slopes in north-central Washington. Res. Note PNW-224. Portland, OR: Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1975. 8 p.

McArthur, E. D.; Hassell, W. G.; Stevens, R.; Davis, J. N.; Stranathan, S. E.; Noller, G. L.; Tiedemann, A. R.; Goodrich, S. K. Notice of naming and release of 'Rincon' fourwing saltbush (*Atriplex canescens*) for wildlife and livestock range and disturbed land reclamation. Washington, DC: U.S. Department of Agriculture, Soil Conservation Service; 1982. 5 p.

Plummer, A. P.; Christensen, D. R.; Monsen, S. B. Restoring big-game range in Utah. Publ. 68-3. Salt Lake City, UT: Utah Division Fish and Game; 1968. 183 p.

Steel, R. G. D.; Torrie, J. H. Principles and procedures of statistics. New York: McGraw Hill; 1960. 481 p.

Stevens, R.; Monsen, S. B.; Shaw, N.; Welch, B.; James, G.; Jorgerson, K. R.; Davis, J. N. Naming and release of 'Paiute' orchardgrass for commercial production and marketing of seed. Washington, DC: U.S. Department of Agriculture, Soil Conservation Service; 1983a. 3 p.

Stevens, R.; Monsen, S. B.; Shaw, N.; McArthur, E. D.; James, G.; Davis, G.; Jorgenson, K. R.; Davis, J. N. Naming and releasing of 'Ephraim' crested wheatgrass for commercial production and marketing of seed. Washington, DC: U.S. Department of Agriculture, Soil Conservation Service; 1983b. 2 p.

West, N. W.; Skujins, J., eds. Nitrogen in desert ecosystems. US/IBP Synthesis Series 9. Stroudsburg, PA: Dowden, Hutchinson, and Ross, Inc; 1978. 307 p.

In: Tiedemann, Arthur R.; McArthur, E. Durant; Stutz, Howard C.; Stevens, Richard; Johnson, Kendall L., compilers. Proceedings--symposium on the biology of *Atriplex* and related chenopods; 1983 May 2-6; Provo, UT. General Technical Report INT-172. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 309 p.

MANAGEMENT AND REHABILITATION OF A BURNED WINTERFAT COMMUNITY

IN SOUTHWESTERN IDAHO

Mike Pellant and Linda Reichert

ABSTRACT: About 3,000 acres (1 200 ha) of winterfat dominated rangeland near Boise, Idaho, were burned by wildfires in September 1981 and August 1982. This paper briefly describes the uses, ecology, and effects of fire on the Snake River Plain winterfat communities and describes the use of a hydroseeder to reseed winterfat. Seeding with a winterfat-grass mixture using a hydroseeder proved feasible but costly. Costs to reseed 500 acres (200 ha) with a hydroseeder averaged $36 per acre ($89 per ha). Advantages in using a hydroseeder include good site selectivity for application of winterfat seed and even seed distribution. However, hydroseeding is labor intensive and requires large quantities of water.

INTRODUCTION

In September 1981 and August 1982 lightning-caused fires burned 3,000 acres (1 200 ha) of winterfat (Ceratoides lanata [Pursh] J.C. Howell) dominated rangelands near Boise, Idaho. Winterfat communities provide good soil stabilization and winter forage for livestock. In addition, they provide essential prey habitat within the Snake River Birds of Prey Area. These burns occurred in an ecologically and economically important area with tremendous watershed, wildlife, and livestock values. For these reasons, two burned winterfat communities were selected for reseeding under the Bureau of Land Management's (BLM) Fire Rehabilitation Program. One thousand acres (400 ha) were seeded in November 1982; another 500 acres (200 ha) were seeded in May 1983. The authors will limit their discussion to the 500-acre (200-ha) seeding near Melba, Idaho, since accurate cost records were kept on this project.

DESCRIPTION OF AREA

The Melba treatment area is 20 miles (32 km) southwest of Boise, Idaho, in the area defined as the Snake River Plains. It is characterized by rolling hills and basaltic buttes. Elevations range from 2,840 to 3,240 feet (866 to 988 m) and slopes are less than 5 percent.

Average annual precipitation is 11.9 inches (30.2 cm) at Swan Falls Dam, 7 miles (11.3 km) south of the Melba treatment area. April through October precipitation averages 5.6 inches (14.2 cm).

April and May rainfall accounts for 70 percent of the total growing season precipitation. January is the coldest month and August is the warmest with mean monthly temperatures of 35.4°F (1.9°C) and 80.8°F (27.1°C) respectively.

Soils supporting winterfat communities are deep silty loams, well drained, and moderately permeable. These soils formed in loess or silty alluvium, thus the potential for wind erosion is severe if vegetative cover is lost. Winterfat communities occur in relatively pure stands (fig. 1) or are associated with big sagebrush (Artemesia tridentata Nutt. ssp. wyomingensis) communities in mosaic patterns. Winterfat densities in the pure stands range from 17,000 to 26,000 plants per acre (41 990 to 64 220 per ha). Understory vegetation is predominantly Sandberg bluegrass (Poa sandbergii Vasey) and cheatgrass (Bromus tectorum L.) with lesser amounts of squirreltail (Sitanion hystrix [Nutt.] J.G. Sm.) and traces of Indian ricegrass (Oryzopsis hymenoides [R&S] Ricker in Piper).

Figure 1.--Typical winterfat community near Melba seeding area.

The Melba treatment area, within the Snake River Birds of Prey Area, is renowned for its diversity and density of nesting birds of prey. An important part of this ecological system is the quality and stability of prey habitat. Some of the most important prey habitat is found in winterfat communities and associated winterfat/big sagebrush mosaics. These areas have high densities of Townsend ground squirrels

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(Spermophilus townsendii), a major prey species of many raptors (U.S. Department of the Interior 1979). Soils associated with the winterfat areas are well-suited for these burrowing ground squirrels.

LIVESTOCK USE

The winterfat stands along the Snake River were widely mentioned in the journals of early settlers (Keith 1938; Fulton 1965; Gibbs 1976). Winterfat or "white sage" provided good cattle feed in the winter (Shirk 1956). As range at higher elevations greened up, cattle were moved to spring and summer ranges. Sheep use followed this same pattern. This trend of winter livestock use has continued to date. Shortly after passage of the Taylor Grazing Act in 1934, allotments were established to regulate livestock numbers and establish spring-fall and winter use areas. Fencing was completed between these seasonal ranges in 1978. Since then 11,000 sheep and 7,000 cattle have grazed the allotment in which this study was conducted from December 16 to February 28 each year.

DROUGHT AND GRAZING EFFECTS

It is well documented that winterfat is drought tolerant (Hilton 1951; Hutchings and Stewart 1953; Plummer and others 1968). An extensive fibrous root system and deep taproot aid this shrub when soil moisture is limiting (Stevens and others 1977). Upon seed germination, lateral roots develop quickly in response to available moisture.

Near the Melba treatment area, nine photo-trend plots were established in 1977 to monitor drought effects on winterfat. Drought conditions were severe in 1976 and 1977. Livestock permittees took a voluntary 50 percent reduction in livestock use to lessen the grazing impacts on winterfat. In 1981 all plots were photographed again and winterfat densities compared. Only one of 80 plants present in the nine plots had disappeared between 1977 and 1981.

Grazing impacts on winterfat have also been studied. Hodgkinson (1975) reported dormant season grazing of up to 80 percent does not adversely affect vigor. However, grazing past 25 percent during the growing season will result in depleted vigor (Stevens and others 1977). Winterfat production was greatest under moderate winter stocking rates in Utah (Hutchings and Stewart 1953).

Effects of moderate winter use can be demonstrated at a winterfat grazing exclosure constructed in 1963, located within 6 miles (9.7 km) of the Melba treatment area. Canopy cover of winterfat was recorded on two permanent transects inside and outside the exclosure. Winterfat canopy cover has remained stable over the past 20 years both inside and outside the exclosure. However, vigor of ungrazed winterfat plants is visibly better than vigor of grazed plants.

FIRE EFFECTS

Whereas drought and grazing affect winterfat primarily by reducing vigor, wildfires significantly alter the composition of winterfat communities.

Frequency of fires in semidesert grass-shrub communities is normally low due to lack of fine fuels (Wright and Bailey 1983). In the Melba treatment area, herbaceous production was well above normal in 1981. Intense wildfires consumed winterfat plants to within 1 inch (2.5 cm) of ground level.

Little information is available on the effects of burning on winterfat. Dwyer and Pieper (1967) reported that winterfat resprouted vigorously after burning in New Mexico. Fire effects on winterfat were studied on a permanent transect established in April 1981, adjacent to the Melba treatment area. Four months after establishing this transect, an intense wildfire occurred. In 1982, 100 percent winterfat mortality, as determined by density measurements, was recorded on the transect. Sandberg bluegrass is now the dominant perennial species.

On different burns in this same area, winterfat mortality is 95 percent when fire is intense. Winterfat plants observed to survive these fires have at least 20 percent annual leader growth remaining. However, objective studies have not been performed to substantiate this observation.

Winterfat seed dispersal normally occurs in September, after wildfires have occurred. Thus intense wildfires normally destroy all seed on plants. Natural regeneration is rare.

Where winterfat has burned, no noticeable reproduction can be observed, even at the zone between the burned and unburned winterfat communities. Sandberg bluegrass and cheatgrass fill the space once occupied by winterfat.

SEED PRESCRIPTION

Winterfat, one native, and one introduced grass species were included in the seed prescription. Table 1 is a list of species and seeding rates used in the rehabilitation project.

Table 1.--Seed mixture applied on the Melba treatment area; seed rates are in bulk pounds per acre.

Species	Pounds per Acre
Winterfat	2.0
Russian wildrye	3.0
Indian ricegrass	.5
TOTAL	5.5

An estimated 200,000 seeds of winterfat (bulk rate) were applied at a rate of 2 pounds per acre (2.24 kg/ha). Our objective in applying winterfat

at 2 pounds per acre was to approximate prefire winterfat densities. Seed viability (determined by a germination test) was 27 percent and purity was 65 percent, yielding pure live seed (PLS) of 30,000 seeds per acre (74 100 per ha). Wasser (1982) recommends planting winterfat at rates of 1 1/2 to 3 pounds per acre (1.68-3.36 kg/ha) broadcasted in total seed mixes of 10 to 20 pounds per acre (11.2-22.4 kg/ha). Also, seeding winterfat with vigorous adapted grasses is recommended where cheatgrass is a competitor.

Russian wildrye (Elymus junceus Fisch.) has low seedling vigor (Wasser 1982); thus it does not provide serious first year competition to winterfat seedlings. This grass also has several desirable traits for prey populations in the area. It greens up early in spring and any regrowth in the fall stays green longer than other commonly seeded grasses (Wasser 1982).

Indian ricegrass was included since it was originally the dominant grass on the winterfat sites (Boise District Range Site Description[1]). Currently, Indian ricegrass is present in trace amounts, primarily near anthills.

Broadcast seeding and covering winterfat seed less than one-quarter inch (0.64 cm) is recommended by several authors (Springfield 1970; Stevens and others 1977). Ferguson and Frischknecht (1981) found autumn broadcasting of winterfat followed by harrowing resulted in a fair stand of winterfat despite some winter mortality. Other authors also recommend fall planting of winterfat (Hodgkinson 1975; Fisser 1981). Statler (1967) and Stevens (1981) had success with spring planting of winterfat.

USE OF HYDROSEEDER

Originally, grass and winterfat seed were to be premixed and broadcast from a Simplex (Model 1620) hydraulic-driven seeder mounted on a helicopter. This proved unfeasible. The light winterfat seed and pieces of stems bridged in the hopper resulting in an effective seeding rate of less than 1 pound per acre (1.12 kg/ha). Also, grass seed had a tendency to settle to the bottom of the hopper. Similar problems were encountered when trying to broadcast winterfat seed with a modified insulation blower or planting it with a rangeland drill. Planting depths of less than one quarter inch (0.64 cm) are not possible with the standard rangeland drill even with depth bands on the disks.

With alternatives exhausted and proper seeding time at hand, a Finn "Bantam 8" hydroseeder was selected to seed the treatment area. No reference was found to indicate this piece of equipment had been previously used to rehabilitate large acreages of disturbed rangeland. Stevens (1981) recommended against using a hydroseeder in arid land seedings because seed is not covered with soil. Therefore, our seed mixture was covered after hydroseeding by pulling a pasture-type harrow one way over the seeded area.

Several modifications to the hydroseeder were required prior to field work. First, the hydroseeder was mounted on a gooseneck trailer and securely chained and boomed. A 1-ton, four-wheel drive pickup pulled the trailer-mounted hydroseeder (fig. 2).

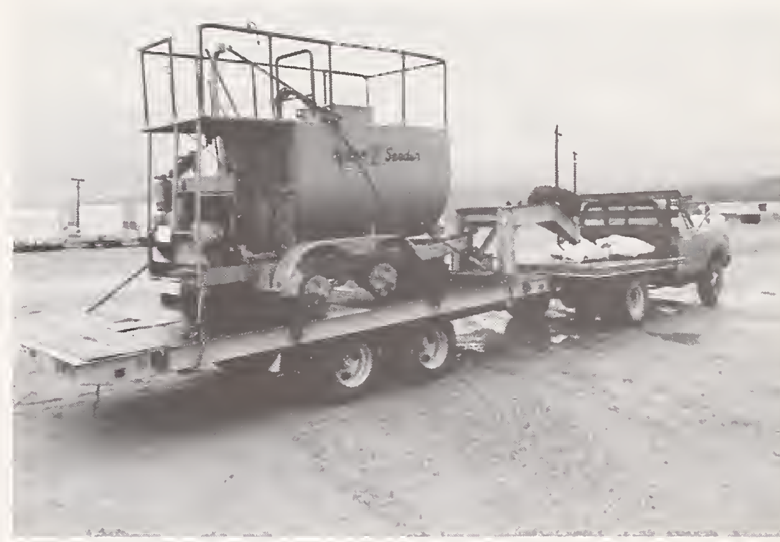

Figure 2--Hydroseeder modified for rangeland seeding.

The hydroseeder tank was filled with 800 gallons (3 030 liters) of water, the agitator blades inside the tank started, and seed added. The grass/winterfat mixture was then forced out a nozzle under pressure. Typically, each 800-gallon load of water and seed could be distributed over 15 acres (6 ha) in 10 minutes. Windspeeds less than 10 miles per hour (16 km/h) and an average vehicle speed of 5 miles per hour (8 km/h) were required to obtain this result. When slopes exceeded 10 percent, topography was broken, or windspeeds exceeded 10 miles per hour (16 km/h), acreage seeded decreased proportionately. Under ideal conditions a swath 120 feet (37 m) wide could be seeded with the hydroseeder.

About 31,000 gallons (117 300 liters) of water were required to seed 500 acres (200 ha). Two trucks with drivers were required to keep the hydroseeder supplied with water. Water was hauled to the treatment area in a 4,000-gallon (15 100-liter) trailer pulled by a semi-truck. Water was pumped from the trailer to a more mobile 2,800-gallon (10 600-liter) water truck which followed the hydroseeder. Access to the treatment area was on good, improved dirt roads for the 34-mile (54.7-km) round trip to obtain water at Kuna, Idaho.

[1]Boise District Range Site Descriptions. Data on file at BLM, Boise District Office, Boise, Idaho; 1982.

A three-person crew was required to operate the hydroseeder. One person drove the truck pulling the hydroseeder, another operated the hydroseeder controls which distributed the seed mixture, while the third gave the truck driver directions over a two-way radio. The "guide" on the hydroseeder deck was necessary to insure that the truck driver would keep the proper distance from the previously seeded areas. From the deck of the hydroseeder, 20 feet (6 m) above the ground, previous passes were easily recognized by wet soil, or presence of white winterfat seeds on the blackened soil.

COSTS

Hydroseeding proved to be expensive (table 2). Costs to reseed 500 acres (200 ha) averaged $36 per acre ($89 per ha).

Table 2.--Average cost to reseed 500 acres with a winterfat-grass mixture near Melba, Idaho.

Item	Cost per acre	Percent of total cost
Planning and survey/design [1]	$ 4	8
Seed [2]	21	59
Hydroseeder operation [3]	7	23
Harrowing	4	10
TOTALS	36	100

[1]Includes costs to prepare the fire rehabilitation plan, flag the treatment area, prepare equipment, and organize personnel.

[2]Costs per pound for the three species: (1) winterfat - $7.25 ($15.95 per kg); (2) Russian wildrye - $0.71 ($1.56 per kg); and (3) Indian ricegrass - $7.67 ($16.87 per kg).

[3]Includes salaries, equipment, mileage, maintenance, and purchase of water. Equipment costs would have been higher if all equipment needed for the project, including the hydroseeder, had not been available within BLM.

By comparison, aerial seeding with a helicopter costs $4-5 per acre ($10-12.50 per ha). All other costs, i.e. planning and survey/design, seed costs, and harrowing are required with aerial seeding as well as hydroseeding. Thus seeding costs are $2-3 per acre ($5-7.50 per ha) higher with a hyrdoseeder than with a helicopter.

ADVANTAGES AND DISADVANTAGES

As with all seeding techniques, especially untested ones, advantages and disadvantages were encountered.

Advantages of applying winterfat with a hydroseeder include:

1. Low seeding rates of a winterfat-grass mix (5.5 pounds per acre; 4.9 kg per ha) could be efficiently applied. Neither a rangeland drill nor an aerial seeder proved feasible in this situation.

2. Site selectivity for application of winterfat seed is good. Rocky areas, prefire sagebrush sites, and small unburned winterfat islands can be avoided, thus promoting the most efficient placement of expensive winterfat seed. This is especially important in complex winterfat/big sagebrush mosaics.

3. Seed distribution is uniform. The continuous mixing action of the hydroseeder promoted even seed distribution.

4. Winterfat causes an allergic reaction in many people. Using a hydroseeder with water as the dispersal agent alleviated this problem.

Disadvantages of hydroseeding include:

1. Hydroseeding in a rangeland situation is labor-intensive, requiring a five-person crew.

2. Equipment, especially the hydroseeder, is not designed for seeding rangelands. Extra precautions and maintenance are required to keep equipment in good working condition.

3. Winterfat seed must be screened to remove all stems greater than one-quarter/inch (0.64 cm) in length. The hydroseeder pump is susceptible to clogging. Cleaning the pump takes 30 to 45 minutes, during which time the seed/water mixture can be lost. However, stems created problems in all seeding methods tested.

4. Weather conditions and terrain affect the speed and efficiency of the operation. Winds greater than 10 miles per hour (16 km/h) significantly limit the width and distribution of seed. Slopes greater than 10 percent place the hydroseeder at too great an angle. The hydroseeder weighs about 9,000 pounds (4 090 kg) when filled with water and is top heavy when mounted on a trailer.

5. Water must be relatively close to the treatment area and on easily accessible roads. Using the hydroseeder when temperatures may drop below freezing necessitates draining and winterizing pumps each night.

SUMMARY

Using a hydroseeder to reseed large acreages of rangeland is unlikely to become a widely used rehabilitation technique. Costs, equipment

required, and manpower needs all preclude the use of a hydroseeder except in specialized situations, i.e., applying winterfat seed in a mosaic vegetation pattern. Other more efficient and less costly techniques to plant winterfat should be developed.

Regardless of the problems associated with seeding winterfat, an effort must be made to save this valuable range, wildlife, and watershed resource in southwestern Idaho. The alternative is replacement of winterfat with much less desirable herbaceous species.

PUBLICATIONS CITED

Dwyer, D; Pieper, R. D. Fire effects on blue grama-pinyon-juniper rangeland in New Mexico. J. Range Manage. 20: 359-362; 1967.

Ferguson, R. B.; Frischknecht, N. C. Shrub establishment on reconstructed soils in semi-arid areas. In: Shrub establishment on disturbed arid and semi-arid lands symposium proceedings; 1980 December 2-3; Laramie, WY. Cheyenne, WY: Wyoming Game and Fish Department; 1981: 57-63.

Fisser, H. G. Shrub establishment, dominance, and ecology on the juniper and sagebrush-grass types in Wyoming. In: Shrub establishment on disturbed arid and semi-arid lands symposium proceedings; 1980 December 2-3; Laramie, WY. Cheyenne, WY: Wyoming Game and Fish Department; 1981: 23-28.

Fulton, A. C. Tales of the trail. Payette, ID: Payette Radio Ltd.; 1965. 378 p.

Gibbs, R. Beckoning the bold: story of the dawning of Idaho. Moscow, ID: University Press of Idaho; 1976. 267 p.

Hilton, J. W. Effects of certain micro-ecological factors on the germinability and early development of Eurotia lanata. Northwest Sci. 15: 86-92; 1951.

Hogkinson, H. S. Evaluation of winterfat (Eurotia lanata) in Washington. J. Range Manage. 28: 138-141; 1975.

Hutchings, S. S.; Stewart, G. Increasing forage yields and sheep production on intermountain winter ranges. Circ. 925. Washington, D.C.: U.S. Department of Agriculture; 1953. 63 p.

Keith, J. R. When the long-horned cattle of Texas came to Idaho territory. Idaho St. Hist. Soc. 16th Rep.: 1937-38: 41-49; 1938.

Plummer, A.; Christensen, D. R.; Monson, S. B. Restoring big game range in Utah. Salt Lake City, UT: Utah Division of Fish and Game; 1968. 183 p.

Shirk, D. The cattle drives of David Shirk from Texas to the Idaho mines, 1871 to 1873. Portland, OR: Champeog Press; 1956. 148 p.

Springfield, H.W. Emergence and survival of winterfat seedlings from four planting depths. Res. Note RM-162. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1970. 4 p.

Statler, G. D. Eurotia lanata establishment trials. J. Range Manage. 20: 253-255; 1967.

Stevens, R.; Giunta, B. C.; Jorgensen, K. R.; Plummer, A. P. Winterfat. Publ. 77-2. Salt Lake City, UT: Utah Division of Wildlife Resources; 1977. 41 p.

Stevens, R. Techniques for planting shrubs on wildland disturbances. In: Shrub establishment on disturbed arid and semi-arid lands symposium proceedings; 1980 December 2-3; Laramie, WY. Cheyenne, WY: Wyoming Game and Fish Department; 1981: 57-63.

U. S. Department of the Interior, Bureau of Land Management. Snake River Birds of Prey Special Research Report. Washington, D.C.: U.S. Department of the Interior, Bureau of Land Management; 1979. 142 p.

Wasser, C. H. Ecology and culture of selected species useful in revegetating disturbed lands in the west. FWS/OBS-82/56. Washington, D.C.: U.S. Department of the Interior, Fish and Wildlife Service; 1982. 347 p.

Wright, H. A.; Bailey, A. W. Fire ecology of United States and southern Canada. New York, NY: John Wiley & Sons; 1983. 501 p.

In: Tiedemann, Arthur R.; McArthur, E. Durant; Stutz, Howard C.; Stevens, Richard; Johnson, Kendall L., compilers. Proceedings--symposium on the biology of Atriplex and related chenopods; 1983 May 2-6; Provo, UT. General Technical Report INT-172. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 309 p.

METHODS AND COSTS FOR ESTABLISHING SHRUBS ON MINED LANDS IN SOUTHWESTERN WYOMING

Forrest Luke and Stephen B. Monsen

ABSTRACT: Several methods were investigated to determine the most cost-effective means for establishing various shrub species on reclaimed surface-mined land at the Black Butte Coal Mine in southwestern Wyoming. Direct seeding was far more cost-effective ($0.18/surviving shrub) than any transplanting method. Transplanting bareroot stock was the most economical transplanting method at $0.41/surviving shrub. Hand transplanting and front-end loader transplanting of mature indigenous shrubs provided excellent plant survival, but incurred high costs ($2.24 and $5.79 per surviving shrub respectively). Shrub species indigenous to the mine site demonstrated the highest adaptability and long-term survival potential. The majority of adapted shrub species were chenopods.

INTRODUCTION

One of the most difficult and often costly aspects of revegetating disturbed lands is shrub establishment. Plant materials adapted to site specific climatic and soil conditions must be selected if establishment is to be successful (DePuit and others 1980; Stevens 1981). In addition, methods that are operational and cost effective should be used to establish the desired shrub density.

Many factors contribute to the success or failure of establishing plants on reclaimed lands. Some, such as soil structure, soil texture, temperature, and average windspeed, are important but cannot be manipulated. Others, such as supplemental irrigation, soil amendments, proper seedbed preparation, and effective ground mulch, can be used to enhance success. The manner in which cultural practices are employed is critical to the success of any revegetation project.

Frischknecht and Ferguson (1979) reported that areas which receive less than 10 inches (25 cm) of annual moisture must be treated with special care if shrubs are to be established by direct seeding. Transplanting bareroot or container stock can often improve shrub establishment. However, plant survival and adaptation are significantly influenced by availability of soil moisture, competition from weedy plants, planting techniques, and fertility of the soil media (Van Epps and McKell 1980). The survival and growth of woody transplants are also dependent on, or influenced by, the presence of mycorrhizae (Cundell 1977). Few woody species are adapted to arid regions and can survive direct seeding or transplanting. Crofts and Carlson (1982) recommend using mature wilding transplants to improve the establishment and natural spread of woody species.

Shrub density standards currently proposed for surface coal mines in Wyoming would require that 450 shrubs per acre (1 110/ha) be established over 90 percent of reclaimed lands, while 4,050 shrubs per acre (10 000/ha) would be required on the remaining 10 percent. These standards are designed to restore wildlife habitat. Therefore, reclamation personnel know precisely what shrub density and diversity standards must be met. They, thus, have the task of selecting the most effective and economical methods to reach those standards. The purpose of this paper is to compare the costs and feasibility of various shrub establishment methods and to report the success of several native shrub species in relation to the methods employed.

STUDY AREA

The study was conducted on reclaimed surface mined lands at the Black Butte Coal Company, Sweetwater County, Wyo. The mine is located approximately 40 miles (64 km) east of Rock Springs at an elevation of approximately 6,600 feet (2 012 m).

The climate is semiarid; mean monthly temperatures range from 66 F (17 C) in July to 20 F (-6 C) in January. Average annual precipitation is approximately 7.5 inches (18 cm), with highest amounts coming from April to June. Moisture received during the October 1981 to September 1982 period was 7.6 inches (19 cm). Moisture was rather evenly distributed throughout the period.

Topography consists of rolling hills with occasional sandstone rock outcrops or cliffs. The study area is drained by Bitter Creek, which flows into the Green River. Undisturbed soils are generally sandy loam in texture. Soil pH generally ranges from 7.0 to 8.0. Salt content varies by site location.

Native vegetation is characteristic of the cold salt-desert shrub community interspersed with sagebrush steppe. Chenopod shrubs and big sagebrush (*Artemisia tridentata* Nutt.) are the

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dominant woody plants. Common chenopod shrubs include Gardner saltbush (Atriplex gardneri[Moq.] D. Dietr), shadscale (Atriplex confertifolia [Torr. & Frem.] Wats.), and black greasewood (Sarcobatus vermiculatus [Hook] Torr.). Principal grasses are thickspike wheatgrass (Agropyron dasystachyum [Hook] Scribn.), Sandberg bluegrass (Poa sandbergii Vasey), and Salina wildrye (Elymus salina Jones).

METHODS

Four different methods of shrub plantings were evaluated in the study: (1) direct seeding, (2) transplanting of 1-0 size bareroot stock, (3) transplanting mature wildings, and (4) transplanting shrub pads using a front-end loader.

Study sites totaling 257 acres (104 ha) were located on regraded overburden dumps during the spring of 1981. The recontoured surface was topsoiled with approximately 8 inches (20 cm) of subsoil and 4 inches (10 cm) of topsoil material. Fertilizer was added at the rate of 40 lb/acre (45 kg/ha) available nitrogen in the spring of 1982 and 75 lb/acre (84 kg/ha) available phosphorus in the fall of 1981.

Direct Seeding

Five shrub species were seeded in conjunction with several grass species and common alfalfa (Medicago sativa L.) in late October 1981 (table 1). Small and/or chaffy seed including winterfat (Ceratoides lanata [Pursh] J. T. Howell), big sagebrush, and rubber rabbitbrush (Chrysothamnus nauseosus [Pall.] Britt.) were broadcast seeded with a large fertilizer spreader and covered by cultipacking. Large-seeded species, including all herbs and the shrubs fourwing saltbush (Atriplex canescens [Pursh] Nutt.) and Gardner saltbush were then drill seeded with a rangeland drill (table 2).

Table 1.--Seed mixture planted at the Black Butte Coal Mine, Sweetwater County, Wyo. 1981.

Species planted	Seeding rate (pounds pure live seed/acre)
Agropyron dachystachyum (thickspike wheatgrass)	3.0
Agropyron spicatum inerme (beardless bluebunch wheatgrass)	2.0
Oryzopsis hymenoides (Indian ricegrass)	3.0
Medicago sativa (common alfalfa)	0.5
Atriplex canescens (fourwing saltbush)	1.0
Atriplex gardneri (Gardner saltbush)	1.0
Artemisia tridentata (big sagebrush)	0.2
Ceratoides lanata (winterfat)	1.0
Chrysothamnus nauseosus (rubber rabbitbrush)	0.3
TOTAL	12.0

Grass seed, comprised of several improved cultivars, was seeded at an intermediate rate of 8 pounds pure live seed (PLS)/acre (9 kg/ha) to reduce initial grass competition to shrub establishment, and yet provide community diversity. A diverse seed mixture was used to assure that one or more species would be adapted to every combination of topography, aspect, and soils. Shrubs were seeded at a rate of 3.5 PLS lb/acre (8 kg/ha). Following seeding, straw mulch was applied at a rate of 2 ton/acre (4 500 kg/ha). A drip irrigation system was installed in late June 1982,

Table 2.--Cost and establishment success of shrub species by direct seeding at Sweetwater County, Wyo.

Species	Seeding rate: [1]PLS lb/acre	Seeding rate: number PLS/acre	Seed plus seeding cost/acre	Established seedlings/ 1,000 PLS	Established seedlings acre	Cost/seedling
Atriplex canescens	1.0	52,000	$20.00	3.30	169	$0.12
Atriplex gardneri	1.0	110,000	35.00	1.80	199	0.18
Artemisia tridentata	0.2	500,000	19.00	0.01	6	3.17
Ceratoides lanata	1.0	110,000	35.00	2.80	308	0.11
Chrysothamnus nauseosus	.3	130,000	28.00	0.50	69	0.40
TOTAL	3.5	902,000	$137.00		751	
AVERAGE				[2]0.83		[3]$0.18

[1]PLS = pure live seed

[2]Average number of established seedlings per 1,000 PLS determined by:

$$\frac{\text{(Total no. established seedling x 1,000)}}{\text{Total number PLS planted}}$$

[3]Average cost per seedling determined by: $\frac{\text{Total acre planting costs}}{\text{Total number established seedlings}}$

but because of late installation, irrigation appeared to have little effect on plant establishment.

Shrub seedling establishment density was evaluated by systematic placement of 26 belt transects, each 3.28 by 82 feet (1 by 25 m), in September 1982. All shrubs rooted within the belt transects were counted toward shrub density. Shrubs per transect area were converted to shrubs per acre with all 26 transects averaged to arrive at the final density figure. The cost per shrub was based on the cost of the seed plus planting costs, divided by the number of shrubs to become established.

Bareroot Transplanting

Shrub seedlings of 10 species (table 3) were hand transplanted from 1-0 bareroot stock in early April 1981 to test their adaptability and survival. Shrubs were planted approximately 6 feet (2 m) apart in rows of up to 25 plants. The planting site was a shallow swale with east- and west-facing slopes. Shrubs were planted on both slopes and in the swale bottom. Soil pH ranged from 7.5 to 8.0. Soil texture was sandy loam. Depth of replaced topsoil was approximately 12 inches (30 cm).

Shrubs were transplanted onto areas that had been fall seeded with the grass-herb mixture (table 1). Understory grasses and broadleaf herbs were not eliminated prior to shrub transplanting, and no attempts were made to control weedy competition during the growing season. Density and ground cover were determined for all understory herbs in October 1982.

Shrub survival was evaluated in October 1982. Different accessions of the same shrub species were evaluated together for this report. The cost per surviving shrub was based on the estimated cost of bareroot plant material plus planting costs. The cost per planted shrub ($0.20/plant) was divided by the percent survival to arrive at the cost per surviving shrub.

Mature Wilding Transplanting

Individual mature healthy plants of five shrub species (table 4) were hand transplanted in mid-May 1982 on a reclaimed overburden dump to evaluate costs and survival and ultimately to test the regeneration potential of shrubs by seed dispersal from mature plants. The study site was located on an approximate 20 percent slope with a north aspect. Reapplied topsoil was approximately 15 inches (38 cm) deep. Soil pH ranged from 7.0 to 7.5. Plants were excavated offsite by hand. Roots were excavated to a minimum of 12 inches (30 cm) and as much soil as possible was left attached to the roots. Shrubs were planted approximately 50 feet (15 m) apart so that each plant would have a relatively large area in which seed could eventually be dispersed. The wildings were transplanted onto sites that were fall seeded with a grass-herb mixture (table 1). Seeded herbs and weedy plants were not controlled during the growing season. Transplanting costs consisted of labor and shrub transport. Plant survival was evaluated in October 1982.

Front End Loader Transplanting

Groups of mature shrubs (pads) were excavated offsite and transplanted onto three recontoured and retopsoiled overburden dump sites in mid-May 1982. A Caterpillar 992C front-end loader with a 12-yd^3 (9 m^3) coal bucket was used to dig and replant the pads. Pads were transplanted by first removing approximately 2 to 3 feet (.6 to 1.0 m) overburden

Table 3.--Cost and first-year survival of bareroot transplants at Sweetwater County, Wyo.

Species	Number individuals transplanted	Number surviving individuals	Survival (%)	Cost/ surviving plant
Amelanchier alnifolia	50	32	64	$0.31
Artemisia nova	44	42	95	0.21
Atriplex canescens	25	21	84	0.24
Chrysothamnus nauseosus	25	7	28	0.71
Ephedra nevadensis	50	6	12	1.67
Ephedra viridis	50	18	36	0.50
Grayia spinosa	25	10	40	0.50
Purshia glandulosa	25	5	20	1.00
Purshia tridentata	125	68	54	0.37
Rhus trilobata trilobata	25	8	32	0.62
TOTAL	444	217		
AVERAGE			[1]49	[2]$0.41

[1]Average plant survival determined by: $\frac{\text{number surviving plants}}{\text{total number planted}}$

[2]Average plant cost per surviving shrub determined by: $\frac{\text{cost per planted shrub (\$0.20)}}{\text{percent survival}}$

Table 4.--Cost and first-year survival of mature wilding transplants at Sweetwater County, Wyo.

Species	Number individuals transplanted	Number individuals surviving	Survival (%)	[1]Cost per surviving plant
Artemisia tridentata	25	25	100	$2.19
Atriplex confertifolia	25	24	96	2.28
Chrysothamnus nauseosus	25	24	96	2.28
Chrysothamnus viscidiflorus	34	34	100	2.19
Sarcobatus vermiculatus	31	30	97	2.26
TOTAL	140	137		
AVERAGE			[2]98	[3]$2.24

[1]Transplanting costs distributed evenly among all species.

[2]Average survival determined by: $\frac{\text{number surviving plants}}{\text{total number planted}}$

[3]Average cost surviving plant determined by: $\frac{\text{cost per planted shrub}}{\text{percent survival}}$

with the front-end loader bucket and then replacing approximately the same amount of soil in which shrubs were rooted. Each pad was approximately 6 by 12 feet (1.8 by 3.6 m). The procedure required one person to operate the loader and another to direct the operator. The most difficult aspect of the front-end loader transplanting operation was removing the shrub pad from the bucket and placing it on the ground so that all shrubs remained vertical without exposing the roots.

A total of 232 shrubs of various species were evaluated in shrub pads totaling approximately 3,000 feet^2 (71 m^2) in October 1982. Transplanting costs included labor and front-end loader operation costs.

RESULTS AND DISCUSSION

Direct Seeding

Shrub density data collected on the 257-acre (104-ha) study site are presented in table 2. Direct seeding produced an average shrub density of 751 shrub seedlings per acre (1 856/ha) which translated to an average return of 0.83 shrub for each 1,000 pure live seeds planted (table 2). Chenopod shrubs comprised over 90 percent of all established seeds. Fourwing saltbush and winterfat were the most successful at producing seedlings relative to the number of seeds planted. Fourwing saltbush provided a return of 3.3 seedlings per 1,000 seeds planted, whereas a figure of 2.8 was recorded for winterfat. Winterfat established the most seedlings per acre, but was seeded at a heavier rate. Establishment of rubber rabbitbrush and big sagebrush was very poor.

Seedling germination and emergence of the seeded shrubs occurred in early May. Most seedlings appeared by mid-June. No germination occurred after this date.

Seeded grasses occupied less than 3 percent ground cover during the period of shrub establishment. The seeded perennials did not appear to influence shrub seedling survival. Annual kochia (Kochia scoparia [L.] Schrad) and halogeton (Halogeton glomeratus C.A. Mey.) germinated and established on the site in the early summer. However, the presence of these two late-germinating weedy species appeared to have had little effect on shrub seedling survival.

Moisture received prior to and during the period of germination was not above normal. Less than 0.8 inch (2.0 cm) was received in May and less than 0.4 inch (1.0 cm) was recorded in June.

Two chenopod species that were not seeded with the regular seed mixture that show promise at the mine site are shadscale and black greasewood. Both species were hand broadcast into swales that were created on the recontoured surface of the study site. Plants established very well, although no quantitative data were taken. Both species will be added to mine seed mixtures beginning in the fall of 1983.

Several practices could be implemented at Black Butte Coal Company that would increase success of direct seeding. Improving the timing and application efficiency of irrigation may improve germination and subsequent seedling survival of seeded shrubs. However, care must be taken that improved grass establishment and competition, as a result of irrigation, does not hinder the slower growing shrub seedlings. Planting grass seed at moderate rates and seeding relatively small patches exclusively to shrubs are other potential means to promote better shrub establishment.

In this study, shrubs were established at a much lower cost by direct seeding than by any method of transplanting. The average cost per shrub from direct seeding ($0.18/established shrub) was only about one-half the cost ($0.41) of the least expensive transplanting method (bareroot transplanting). Direct seeding was also faster and easier to implement.

Establishing shrubs from seed does have limitations, however. Perhaps the biggest limitation is that establishment is very erratic, depending on climatic and edaphic conditions. Adaptability, quality, and availability of native shrub seed can also create problems. Finally, the difficulty of establishing certain species from seed using current methods of seeding makes it almost imperative that such species be transplanted if they are to be established.

Bareroot Transplanting

First year survival and cost per surviving plant for ten shrub species are presented in table 3. Total average survival (49 percent) is slightly misleading; several of the species tested appeared to be poorly adapted to mine site conditions. Although skunkbush sumac (*Rhus trilobata* Nutt.), desert bitterbrush (*Purshia glandulosa* Currant.), antelope bitterbrush (*P. tridentata* [Pursh.] DC), and Saskatoon serviceberry (*Amelanchier alnifolia* [Nutt.] Nutt.) demonstrated relatively good survival (42 percent), most transplants generally were not vigorous and long-term survival appeared tenuous.

Two species, black sagebrush (*Artemisia nova* A. Nels.) and fourwing saltbush, demonstrated excellent first-year survival and were also very vigorous. Rubber rabbitbrush and spiny hopsage (*Grayia spinosa* [Hook.] Moq.) had relatively poor survival, partially as a result of poor transplanting stock, but surviving plants were growing well and appeared to be well adapted. The mean survival among these four adapted species was 63 percent.

Cost per surviving shrub incurred for the establishment of the four adapted shrubs was $0.36. Since transplant survival was considerably higher for these four species, costs per established shrub are reduced. Costs could be further reduced if adapted and healthy stock was utilized.

Nearly all transplant losses occurred immediately after planting. Failure to establish accounted for the major loss among all species. Although the sites received only a normal amount of moisture, few transplants appeared to be under stress during mid-summer. Competition from seeded species and weeds did have some influence on less adapted species. Weedy competition was not evident during the latter part of the growing season.

Van Epps and McKell (1980) suggested that bareroot plantings should be observed for a minimum of 3 to 4 years before transplanted shrubs can be considered permanently established. Crofts and Carlson (1982) determined the average survival rate of bareroot transplants at a number of mines in the Western States was 62 percent for the first year, but dropped to 45 percent at the end of 5 years. Thus, the 63 percent first-year survival rate of the four shrub species in this study is similar to that cited by Crofts and Carlson.

The economics of bareroot transplanting should be based on the use of adapted shrub accessions and the most efficient planting methods available. Selecting adapted shrub accessions must be done through the use of selection test plots and site-specific revegetation experience. The most cost efficient manner of transplanting would appear to be contracting with an experienced tree planting company. Whether mechanical or hand planting methods are used would depend upon topographic conditions.

From a cost standpoint, bareroot transplanting was more effective than either mature wilding transplanting ($2.24 plant) or front-end loader transplanting ($5.79/plant), but was less cost effective than direct seeding. Transplanting could be used to supplement direct seeding and to increase shrub diversity by adding adapted species that do not establish well from seed, or to increase the density of shrubs above that achieved by direct seeding.

Mature Wilding Transplanting

Table 4 presents first-year survival rates and cost per surviving plant for the five species transplanted as mature wildings. Survival for all species approached or equaled 100 percent. However, the technique is labor-intensive and the cost per established plant may prohibit its use. Methods of planting must be determined by other criteria important to individual mine companies.

A final determination of the effectiveness of hand transplanting indigenous plant material must wait for a minimum of two or more growing seasons to evaluate regeneration of shrubs by seed dispersal from sexually mature plants. If successful, seedling establishment could substantially lower costs of shrub establishment.

Transplanting Pads

Table 5 summarizes the costs and first-year survival of seven shrub species transplanted in pads with a front-end loader. All of the transplanted species demonstrated high survival. Surviving plants were vigorous and the potential for long-term survival appeared to be excellent. Soils were moist at the time of transplanting. However, the sites did not receive an unusual amount of moisture prior to or immediately after planting. Pads were adequately placed to eliminate drying of the soil.

Despite the success of transplanting shrub pads with a front-end loader, high costs associated with the technique may limit its use for large-scale shrub establishment. Costs could possibly be reduced 50 percent through increased transplanting efficiency. This is a reasonable expectation with additional experience. However, the cost per established shrub would still be many times higher than that for direct seeding or bareroot transplanting.

However, placement of mature shrub pads offers many advantages. Shrub pads include topsoil with active microorganisms, insects, native forbs, and grasses

Table 5.--Cost and first-year survival of front-end loader transplants at Sweetwater County, Wyo.

Species	Number individuals transplanted	Number individuals surviving	Survival (%)	Cost/ surviving plant
Artemisia spinescens	11	7	64	$7.05
Artemisia tridentata	86	67	78	5.79
Atriplex confertifolia	18	15	83	5.39
Atriplex gardneri	4	4	100	4.49
Chrysothamnus viscidiflorus	15	15	100	4.49
Grayia spinosa	90	64	71	6.32
Sarcobatus vermiculatus	8	8	100	4.49
TOTAL	232	180		
AVERAGE			[1]78	[2]$5.79

[1]Average survival determined by: $\frac{\text{number surviving plants}}{\text{total number planted}}$

[2]Average plant cost per surviving plant determined by: $\frac{\text{cost per planted shrub}}{\text{percent survival}}$

that are capable of spreading into adjacent areas. They provide immediate wildlife habitat and islands for shrub seed dispersal (Crofts and Carlson 1982), and they can be used to stabilize drainage channels and to provide esthetic diversity. Additional shrubs may be gained by seed dispersal which would decrease shrub establishment costs.

The best time to schedule loader transplanting is after recontouring of overburden has been completed and before topsoil is replaced. This sequence eliminates disturbance of reclaimed soils and plants. In addition, shrub pads should normally be taken from sites where topsoil is to be stripped, preferably sites in close proximity to the recontoured area.

SUMMARY AND CONCLUSIONS

Several methods of establishing native shrubs on reclaimed surface-mined land at Black Butte Coal Company in southwestern Wyoming were investigated. The survival success, apparent adaptability of various shrub species, and costs of establishment were also discussed in relation to the shrub establishment techniques.

Data in this report represent first-year shrub establishment results and thus are preliminary. However, differences in the cost for establishing shrubs among methods were sufficiently large to suggest some general conclusions.

Direct seeding appears to be the most cost efficient method for establishing most shrubs evaluated on the study area. Establishment of shrubs from bareroot transplants was found to be less cost effective than direct seeding, but more effective for establishing certain shrub species. Bareroot transplanting may be used to supplement direct seeding for increasing shrub diversity or, as regulations dictate, to increase overall shrub density.

Methods for transplanting excavated mature indigenous shrub species, although very successful, were found to be the most expensive. However, these methods could be implemented for certain site specific uses. Natural spread of seed from the transplanted sites may eventually occur, and would thereby reduce the cost of establishing desirable shrubs.

PUBLICATIONS CITED

Crofts, K. A.; Carlson, K. E. Transplanting techniques used in the establishment of native vegetation. In: Cuary, R. L.; Etra, J. eds. High-altitude revegetation workshop No. 5; Proceedings of symposium; December 1982; Fort Collins, CO: Colorado State University. Info Series No. 48-58-78. 1982: 58-78.

Cundell, A. M. The role of microorganisms in the revegetation of strip-mined land in the Western United States. Journal of Range Management 30(4): 299-305; 1977.

DePuit, E. J.; Coenenberg, J. G.; Skilbreed, C. L. Establishment of diverse native plant communities on coal surface-mined lands in Montana as influenced by seeding method, mixture and rate. Res. Rep. 163. Bozeman, MT: Montana State University Reclamation Research Unit, Montana Agricultural Experiment Station; 1980. 64 p.

Frischknecht, Neil C.; Ferguson, Robert B. Revegetating processed oil shale and coal spoils on semi-arid lands. Interagency Energy-Environment Research and Development Report EPA-600/7-79-068: Cincinnati, OH: U.S. Environmental Protection Agency 1979. 48 p.

Stevens, R. Techniques for planting shrubs on wildland disturbances. In: Stelter, L. H.; DePuit, D. J.; Mikol, S. A., tech. coords. Shrub establishment on disturbed arid and semi-arid lands. December 1980; Laramie, WY. Cheyenne, WY: Wyoming Game and Fish Department; 1981: 29-36.

Van Epps, G. A.; McKell, C. M. Revegetation of disturbed sites in the salt desert range of the Intermountain West. Utah Agricultural Experiment Station Land Rehabilitation Series 5. Logan, UT: Utah State University, Utah Agricultural Experiment Station; 1980. 37 p.

In: Tiedemann, Arthur R.; McArthur, E. Durant; Stutz, Howard C.; Stevens, Richard; Johnson, Kendall L., compilers. Proceedings--symposium on the biology of Atriplex and related chenopods; 1983 May 2-6; Provo, UT. General Technical Report INT-172. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 309 p.

PERFORMANCE OF CHENOPODIACEAE SPECIES ON PROCESSED OIL SHALE

Neil C. Frischknecht and Robert B. Ferguson

ABSTRACT: In 1976, shale revegetation studies began at Sand Wash in Utah's Uinta Basin. Several chenopod species were seeded and/or transplanted onto processed oil shale sites to determine viability. Soil depths, types, and irrigation were varied by plot. At site 1, highest survival rates were by Atriplex obovata Moq., Atriplex bonnevillensis C. A. Hanson, and Kochia prostrata (L.) Schrad. Kochia prostrata and Camphorosma monspeliacum L. were most prolific. At site 2, Atriplex gardeneri and Kochia prostrata had the highest survival rate, followed by the hybrids A. cuneata, A. idahoensis, and A. aptera.

INTRODUCTION

Forest Service research on revegetation of processed oil shale began in the spring of 1976 at two major sites: Sand Wash, in the salt-desert shrub zone of eastern Utah's Uinta Basin, and Davis Gulch, in the upper mountain brush zone of western Colorado. The Sand Wash site is located approximately 32 miles (51 km) south of Vernal, Utah, on land owned by the State of Utah and leased to The Oil Shale Company (TOSCO). The Davis Gulch site is on land owned by the Colony Development Corporation, of which TOSCO is a partner.

Previous research showed that TOSCO II processed oil shale is highly saline, highly alkaline, low in available P and N, and relatively low in available K, with a texture similar to silt loam (Schmehl and McCaslin 1973). Unleached processed shale had a saturation extract conductivity of 13.0 mmhos/cm (Berg 1973). Heavy leaching with water in the amount of 47 to 60 inches (119 to 152 cm) was required to reduce the saturation extract conductivity to within a range suitable for grasses to grow.

Our approach included the use of salt-tolerant shrubs of the Chenopodiaceae family that did not require leaching of salts for plant survival and growth. Two studies at the Sand Wash site involved 28 Chenopodiaceae species or accessions, most of which belonged to the genus Atriplex. Other genera included Ceratoides, Grayia, Sarcobatus, Kochia, and Camphorosma. Species of the latter two genera were introduced from the Soviet Union. At Davis Gulch, only Atriplex canescens (Pursh) Nutt. and Kochia prostrata (L.) Schrad. were tested along with several non-Chenopodiaceae species (Ferguson and Frischknecht 1983). At this higher elevation, the two chenopod species exhibited excellent growth under all treatments and were the most outstanding on processed shale.

PLANT DESCRIPTIONS

Descriptions of three introduced species used in these studies are presented here as derived from Komarov (1936). Descriptions of the other species may be found in Blauer and others (1976) and Stutz[1]. Kochia prostrata (L.) Schrad., a polymorphic undershrub native to Eurasia, is 4 to 30 inches (10 to 75 cm) high with ascending branches covered with short, crisp hairs. Leaves are linear to filiform, flat, and hairy. The inflorescence is spiciform or paniculate; glomerules are remote, mostly in groups of three or four. Perianth is hairy. Dorsal appendages of fruiting perianth are reddish, either rounded, flat, tuberclelike, or oblong winglike, narrowing toward the base, and are scarious, with darker nerves, and rounded toothed on the margin. Seeds are rounded-oval to subrotund, about .075 inch (2 mm) in diameter, with a prominent annular embryo, convex at the center on both sides, brown, naked, and smooth. Kochia prostrata flowers from July to September. The plant grows on clay soils, stony slopes, chalk, sandy steppes, and sandy plains. It is used for fuel by nomads in semi-desert and desert regions. It is eaten readily by horses, camels, sheep, and goats. In its native habitat, the plant is often found growing in association with the crested wheatgrasses (Agropyron cristatum and A. desertorum).

Kochia prostrata var. villosissima Bong. et Mey. Verz. is a white villous race associated with sandy habitats of the semi-desert zone.

Camphorosma monspeliacum L. is described as a dense caespitose undershrub 4 to 20 in (10 to 50 cm) high. Annual shoots having short crisp hairs

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[1]Stutz, H. C. Breeding superior plants for disturbed lands. Unpublished paper presented at Weglen Mined Land Rehabilitation Workshop, Fort Collins, Colorado. June, 1982.

are borne on the woody branches. Leaves are subulate, .118 to 0.4 inches (3 to 10 mm) long, erect or more rarely recurved. Flowers are solitary in a short compact spire, the subtending bracteoles as long as or shorter than the flowers. Perianth is .118 to .38 inches (3 to 35 mm) long densely covered with hairs. Seeds are oval or oblong, brown or brownish black, and diffusely glandular. Camphorosma monspeliacum is found on clay soils, also gravelly slopes. According to Komarov (1936), the plant contains about 0.2 percent volatile oils with the scent of bitter almonds which yield propylamine upon distillation with KOH. The plant has an odor of camphor and has been used for medicinal purposes as a stimulant, diuretic, and diaphoretic. It is used as forage for camels, sheep, and goats in desert regions. We have not detected the camphor odor, nor have we made chemical analyses of the plant. We observed that this species was eaten more readily than others by cottontail rabbits that got inside the enclosure at Sand Wash.

Seed that came to us as Ceratoides papposa (no author) in 1975 from the Agriculture Research Service in Logan, Utah was a derivative of an introduction PI 371860, Eurotia ceratoides (L.) C.A.M. from Russia in 1972. Russian literature (Komarov 1936) describes this species as a small shrub 15.7 to 39 inches (40 to 100 cm) high; leaves entire, 1-nerved, oval, oblong, ovate-lanceolate, or linear-lanceolate with a short petiole. The fruit is obovoid, about .118 inch (3 mm) long, covered with oppressed hairs and some stellate hairs. Flowering occurs July to September. In its native habitat, the plant is gathered for fuel in local regions and is eaten by camels. Its economic importance was greatest in the Pamir high deserts.

Robertson (1982) has described a separate (1962) introduction of Eurotia ceratoides (L.) C.A.M. (Pamirian winterfat) from the U.S.S.R. Pamir Research Station and Academy of Science as a promising species for arid ranges in Nevada. It is described as being a highly variable and pliable species with several races being identified.

SAND WASH STUDIES

Site 1

The first study at Sand Wash involved testing 15 accessions of plants on different depths of soil covering processed shale, ranging from no covering over shale to soil 3 feet (0.91 m) deep over processed shale. Approximately 375 tons (340 metric tons) of TOSCO II processed shale were transported by trucks from Colony Development operations at Parachute, Colo., to the site at Sand Wash. The shale was spread and compacted approximately 2.5 feet (0.76 m) deep in a V-shaped ravine that had been prepared for that purpose (fig. 1). Soil that had been removed in shaping the ravine was spread over the center portion of the shale in the form of a double-edged wedge varying in depth from 0 at the two outside edges to 3 feet (0.9 m) in the center of a linear area 40 feet (12 m) wide and 75 feet (23 m) long.

Dividing the area lengthwise in the center allowed for four strips, each 5 feet (1.5 m) wide, on each side of the center line. These were used as four treatments having different depths of soil over processed shale from the outside edges towards the center as follows:

1. No soil covering processed shale, but 2.5 inches (6.35 cm) of sewage sludge rotovated into the top 8 inches (20 cm) of the shale.

2. Processed shale covered with 0 to 1 foot (0 to 30.5 cm) of replaced soil.

3. Processed shale with 1 to 2 feet (30.5 to 61 cm) of soil covering.

4. Processed shale with 2 to 3 feet (0.61 to 8.91 m) of soil covering.

Plots were small (2.5 by 5 ft [0.76 by 1.5 m]) with four replications in a randomized-block split plot design. Plants that had been grown in containers in the greenhouse for approximately 4 months were transplanted in the field on May 4, 1976. Supplementary water was added by drip irrigation to two replications on five occasions during the first summer, and twice the second summer. The drip irrigation system applied water at the rate of 1 gallon (3.8 liters) per hour to each plant, but it ran for only 15 minutes on most occasions. Twice the first summer, water was applied for 30 minutes at a time.

Site 2

The second study at Sand Wash involved a comparison of container-grown transplants with plants from direct seeding, and also a comparison of two different types of soil covering over shale.

In late September 1976, 475 tons (431 metric tons) of processed shale were transported by truck from the Colony Development site at Parachute Creek, Colo., to an experimental site at Sand Wash a short distance from the first site. The top 8 to 12 inches (20 to 30 cm) of soil from an area 50 feet (15.2 m) wide and 100 feet (30.5 m) long at the end of a small basin was stockpiled, and the area was leveled for placement of the processed shale. The processed shale was spread over the area to a depth of approximately 30 inches (0.76 m). Washed gravel about 1 inch (2.5 cm) in size

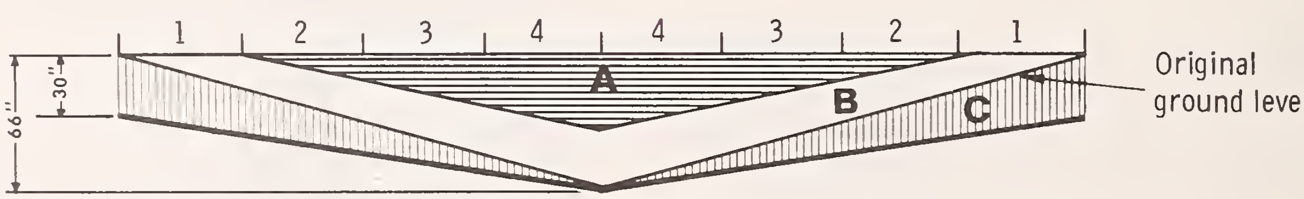

Figure 1.--Cross-section of experimental site depicting cut in native soil (C), processed oil shale fill (B and C), and native soil fill (A).

was spread to a depth of 6 inches (15.2 cm) over half of the area covered by processed shale and the graveled area then covered with native soil to a depth of 1 foot (30.5 cm). Native soil was spread over the other half of the processed shale to a depth of 18 inches (0.46 m).

On December 14, 1976, seeds of 24 chenopod shrubs were planted in single rows and replicated four times for comparison with container-grown plants of the same species. Plots were 5 feet (1.5 m) wide and 10 feet (3 m) long. Each plot contained one row of fall-planted seed and one row of container-grown plants. Rows were spaced 30 inches (0.76 m) apart, and container-grown plants within rows were also spaced 30 inches apart. This allowed four times as much space per plant as in the first study.

RESULTS

Site 1

Table 1 shows percent survival of seven chenopods in 1982, 6 years following the first planting. Highest percent survival was exhibited by Atriplex obovata Moq., Atriplex bonnevillensis C.A. Hanson, and Kochia prostrata, with Atriplex tridentata Kuntze not far behind. Kochia prostrata var. villosissima was not planted in all replications due to shortage of plants and is not shown in the table, but it was planted in all treatments. This species showed 100 percent survival where planted, but fewer plants were involved than for the other species.

Results at the end of the second growing season (1977) showed that supplementary water had the most beneficial effect on the plots of processed shale where no soil covering was applied, and that the advantage of watering tended to disappear with increasing depth of topsoil over shale (Frischknecht and Ferguson 1979). Although plants received no supplementary water after 1977, benefits of the early irrigations were evident to some degree in 1982 (table 1).

From the standpoint of reproduction, K. prostrata (both varieties) and Camphorosma monspeliacum L. were by far the most prolific. Seeds of these species are small, and whatever amount of soil covering was required for germination and establishment was provided by conditions associated with overwintering. Some Kochia and Camphorosma plants became established outside the exclosure in bare spaces in the native vegetation, probably from seeds collected by small rodents. A few new plants of all three Atriplex species established from seed, but the number was small compared to Kochia and Camphorosma.

Seeds of the three introduced species (K. prostrata, C. monspeliacum, and Ceratoides papposa) were brought to this country through efforts of Dr. Wesley Keller (retired), formerly with the Agricultural Research Service (ARS). The A. bonnevillensis used in the study came from seeds collected from plants growing on a playa at the Desert Experimental Range in southwestern Utah. Atriplex tridentata came from seeds collected in Rush Valley, Utah, and A. obovata from seeds collected near the Hatch Trading Post in southeastern Utah. Ceratoides lanata (Pursh) J.T. Howell came from seeds collected at two places; near the Desert Experimental Range, and near Duchesne in Utah's Uinta Basin. Few or no differences were observed in survival of plants from these two origins.

In addition to the species shown in table 1, a limited number of container-grown plants was obtained from Dr. Howard Stutz, geneticist, Brigham Young University, for use in the 1976 study at Sand Wash. These included 16 plants each of nine species or accessions of Atriplex as follows: Atriplex canescens from Jericho and Emery in Utah, and White Sands, N. Mex.; Atriplex aptera from Bridger, Mont., and Edgar, Mont.; A. obovata from San Ysidro, N. Mex.,; A. lentiformis (Torr.) Wats. from St. George, Utah; A. polycarpa (Torr.) Wats. from Sonoma, N. Mex.; and an undescribed taxon from San Roberta, Mexico. The latter three species had no survivors in 1982; most of the plants died during the first or second winter. The A. canescens from White Sands survived through the first three growing seasons but died in the third winter. Accessions of A. aptera, both accessions of A. canescens from Utah, and the A. obovata from New Mexico had some surviving plants in 1982.

Results of this study indicate that processed shale should be covered with at least 1 foot of topsoil for best establishment and survival of plants.

Table 1.--Percent survival of seven chenopods in 1982, six years after planting, Site 1.

	Irrigated 1976-77					Nonirrigated				
	Soil depth over shale, ft					Soil depth over shale, ft				
Species	None	0-1	1-2	2-3	Mean	None	0-1	1-2	2-3	Mean
Atriplex bonnevillensis	56	81	100	88	81.2	69	81	81	81	78.0
A. obovata	69	75	88	100	83.0	62	94	89	94	84.8
A. tridentata	50	62	88	50	62.5	69	88	50	62	67.2
Camphorosma monspeliacum	38	62	44	56	50.0	19	81	56	62	54.5
Ceratoides lanata	0	44	50	38	33.0	0	12	75	38	31.2
C. papposa	6	62	81	75	56.0	0	31	44	75	37.5
Kochia prostrata	88	81	69	81	80.0	50	69	75	94	72.0
Mean	43.8	66.7	74.3	69.7	63.6	38.4	65.4	67.1	72.3	60.8

Site 2

The second study at Sand Wash involved comparing the growth and survival of container-grown plants set out in the spring with plants established by direct seeding the previous fall. Sparse germination resulted from fall-planted seeds because of drought in the winter of 1976-77. Although 18 of the species showed a little germination in May, only 14 species had plants surviving by fall. All seed rows were replanted in the fall of 1977 to the same species, and excellent germination resulted in the spring of 1978. In fact, it appeared that many ungerminated seeds from the original planting germinated in the second year. Some of the ungerminated first-year seed had been scraped just outside the original rows in making the second planting.

Some thinning was done in the rows established from seeds so that these plants would have somewhat comparable room for growth as the transplants from containers.

Percent survival and average height of the container-grown plants are shown in table 2. Survival is not shown for plants from seeds because the numbers of plants after thinning were not equal. Also, additional germination occurred after the thinning. Generally speaking, the number of surviving plants from seed was equal to or greater than the number of survivors from container-grown plants. In some instances, plants from containers were larger in 1982 than those established from seed, but most were comparable in size. Superior survival of container-grown plants 5 years following planting was exhibited by the two ecotypes of K. prostrata. Reproduction of these plants was superior to any other species. Kochia prostrata var. villosissima was more prolific than the other ecotype, which is greener in color because of less pubescence. Most plots of Atriplex were invaded to some extent by new plants of Kochia.

Table 2.--Percent survival and average height of 24 chenopods in 1982, five years after establishment by transplanting, Site 2.

Species	Origin	Survival (percent)	Height (inches)	Height (cm)
Atriplex aptera	Scenic, S. Dak.	81	12	30
A. aptera	Circle, Mont.	6	14	36
A. aptera	Drumheller, Alberta	0	--	--
A. aptera	Crawford, Neb.	50	19	48
A. canescens	Jericho, Utah	31	42	107
A. canescens	White Sands, N. Mex.	12	24	61
A. canescens	Thermopolis, Wyo.	56	9	23
A. canescens	Eureka, Nev.	9	13	33
A. canescens	Uinta Basin, Utah	84	26	66
A. lahontanensis[1]	Battle Mountain, Nev.	44	11	28
A. navajoensis	Navajo Bridge, Ariz.	12	11	28
A. gardneri	Worland, Wyo.	94	8	20
A. tridentata	Uinta Basin, Utah	75	16	41
A. confertifolia	Rush Valley, Utah	[2]--	--	--
Atca x A. idahoensis	Grandview, Idaho	94	13	33
Atca x A. cuneata	Hanksville, Utah	88	16	411
Atca x A. tridentata	Skull Valley, Utah	44	10	25
Atca x A. nevadensis[1]	Marble Mine, Nev.	75	11	28
Ceratoides lanata	Sanpete County, Utah	38	13	33
Grayia spinosa	Uinta Basin, Utah	56	12	30
Camphorosma monspeliacum	Soviet Union	75	9	23
Kochia prostrata	Soviet Union	94	16	41
K. prostrata var. villosissima	Soviet Union	94	17	43
Sarcobatus vermiculatus	Uinta Basin, Utah	75	15	38

[1]Undescribed taxa, provided by Dr. Howard Stutz.
[2]Container-grown plants not available.

PUBLICATIONS CITED

Berg, W. A. Chemical analyses of TOSCO II processed shale and their interpretations relative to plant growth. In: Block, M. B.; Kilburn, D. D., eds. Processed shale revegetation studies. Denver, CO: Colony Development Corporation; 1973: 115-127.

Blauer, A. Clyde; Plummer, A. Perry; McArthur, E. D.; Stevens; Richard; Giunta, Bruce. Characteristics and hybridization if important Intermountain shrubs. II. Chenopod family. Res. Pap. INT-177. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1976. 42 p.

Ferguson, Robert B.; Frischknecht, Neil C. Revegetating processed oil shale in the upper mountainbrush zone of Colorado. Res. Pap. INT-321. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1983. 9 p.

Frischknecht, Neil C.; Ferguson, Robert B. Revegetating processed oil shale and coal spoils on semi-arid lands. USDA-EPA 600/7-79-068. Cincinnatti, OH: U.S. Environmental Protection Agency; 1979. 47 p.

Komarov, F. L., ed. Flora of the USSR. Vol. VI. Centrospermae. Transl. from Russian, 1970. Jerusalem, ISRAEL: Israel Program for Scientific Translations; 1936. 731 p.

Robertson, Joseph H. Pamirian winterfat (Eurotia ceratoides (L.) C.A.M.): a versatile shrub for western ranges. Mentzelia. 5: 33-36; 1982.

Schmehl, W. R.; McCaslin, B. D. Some properties of spent oil shale significant to plant growth. In: Block, M. B.; Kilburn, P. D., eds. Processed shale revegetation studies. Denver, CO: Colony Development Corporation; 1973: 7-25.

In: Tiedemann, Arthur R.; McArthur, E. Durant; Stutz, Howard C.; Stevens, Richard; Johnson, Kendall L., compilers. Proceedings--symposium on the biology of Atriplex and related chenopods; 1983 May 2-6; Provo, UT. General Technical Report INT-172. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 309 p.

SEEDING SHRUBS WITH HERBS ON A SEMIARID MINE SITE WITH AND WITHOUT TOPSOIL

Stephen B. Monsen and Bland Z. Richardson

ABSTRACT: The establishment and survival of shrubs seeded in a mixture with herbs on topsoil and mine waste materials were compared in north-central Nevada. Topsoil provided an improved seedbed for all species planted. Fourwing saltbush, rubber rabbitbrush, and forage kochia all established and grew well under both topsoil and control treatments. Shadscale saltbush did not persist on either treatment. Wyoming big sagebrush established and grew satisfactorily only on the topsoil treatment. A higher percentage of fourwing saltbush seeds germinated and became established than any other seeded shrub. Seeding shrub and herb seeds together did not appear to result in seedling losses due to plant competition. Shrub seedlings were better adapted to the barren treatment than the herbs. Cultipack seeding was a successful method of planting seeds of different size and shape.

INTRODUCTION

Mining has been an important industry in north-central Nevada since settlement. Revegetation of most mined areas has not been attempted because of costs and low productivity, but restoration of mined areas is often necessary to reduce further degradation and limit impacts to associated soils, watershed, and wildlife resources.

Mining in north-central Nevada occurs over an extensive area where the average annual precipitation is less than 16 inches (40 cm). Infertile soils are also characteristic. These conditions significantly reduce the success of revegetation by limiting the establishment of seedlings and the persistence of older plants. Nicholas and McGinnies (1982) determined that applying topsoil to mine disturbances increased herbage and root production of seeded plants. In addition, Cundell (1977) found that fertilizer and inoculation of the rhizosphere with heterotrophic nitrogen-fixing bacteria improved reclamation of mined sites.

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Few native or introduced species are adapted to semiarid mine disturbances. To date, most revegetation efforts have relied upon the use of grasses that have been developed for wildland plantings (Lawrence and Troelsen 1964; Gomm 1974; Wilson and Smoliak 1977; Lawrence 1981). Although these plants are useful and possess desirable characteristics, not all mined disturbances can be satisfactorily restored with grasses. Even the most tolerant grass cultivars may succumb to adverse conditions (Currie and White 1982).

Relatively few native shrubs or broadleaf herbs have been thoroughly evaluated for revegetating mined areas. However, Ferguson and Frischknecht (1981) identified various shrubs and herbs that are adapted to semiarid sites within the Intermountain region and can enhance forage yields and ground cover. Plummer and others (1968) reported that seeds of big sagebrush (*Artemisia tridentata* Nutt.), rubber rabbitbrush (*Chrysothamnus nauseosus* [Pallas] Britt.), fourwing saltbush (*Atriplex canescens* [Pursh] Nutt.), and common winterfat (*Ceratoides lanata* [Pursh] J. T. Howell) germinate readily and developed competitive seedlings in range and wildlife plantings. Stevens and others (1981) reported that forage kochia (*Kochia prostrata* [L.] Schrad.), a recent introduction from the U.S.S.R., also performs well in range seedings. DePuit and Coenenberg (1979), Aldon (1981), and Holechek and others (1981) found that fourwing saltbush is particularly well adapted to mixed plantings on mine spoils.

Direct seeding of shrubs has not always been a dependable method of plant establishment under semiarid conditions (Van Epps and McKell 1980). Erratic seed germination and competition between developing shrub and grass seedlings has limited shrub establishment (Howard and others 1979; Aldon and Pase 1981).

This study was initiated to determine the compatibility of various woody shrubs and herbs seeded on an abandoned mined site in north-central Nevada. The effects of topsoiling to enhance seedling establishment and plant growth were also evaluated.

METHODS

Plantings were established on the Beacon Pit Mine, located about 12 miles (20 km) southeast of Battle Mountain, Lander County, Nev. Approximately 100,000 tons (90 719 metric tons) of barite ore had been mined from the site. The ore was removed from

an open pit approximately 600 feet (183 m) long, 250 feet (76 m) wide, and 60 feet (18 m) deep. The waste rock and overburden material have been sidecast near the pit. Prior to planting, the waste dump was leveled. A portion of the dump was topsoiled to a depth of approximately 5 inches (12 cm). An adjacent portion of the dump was not topsoiled, but left as the control treatment.

Topsoil was taken from an area adjacent to the mine. The native collection site supported a dense stand of Wyoming big sagebrush (*Artemisia tridentata* Nutt. ssp. *wyomingensis* Beetle and Young) with a scattered understory of bunchgrass and cheatgrass brome (*Bromus tectorum* L.). Rubber rabbitbrush was intermixed with the Wyoming big sagebrush, but occurred as a minor element in the shrub-dominated community. However, rubber rabbitbrush had spread onto abandoned mine disturbances along with halogeton (*Halogeton glomeratus* C.A. Ney) and cheatgrass brome. Scattered stands of shadscale saltbush (*Atriplex confertifolia* [Torr. & Frem.] Wats.), Nevada ephedra (*Ephedra nevadensis* Wats.), and common winterfat also occurred near the mine.

The study sites were prepared and planted December 3 to 6, 1978. Following application of the topsoil, both the control and topsoil areas were fertilized, harrowed, and seeded. Fertilizer was applied at a rate of 50 pounds per acre (56 kg/ha) using a commercial fertilizer with nitrogen, phosphorus, and potassium in a ratio of 16-16-16.

A seed mixture consisting of five species of grass, four broadleaf herbs, and five shrubs was planted on both the topsoil and control sites using a Brillion cultipack seeder. Vallentine (1980) describes the features of this seeder. Seeds of all species were mixed and seeded together. The species planted and seeding rates are listed in table 1.

In June 1979, the new plantings were fenced to prevent rabbit depredation. A precipitation gage was established at the study on February 2, 1979. Moisture received was recorded on a monthly basis throughout the duration of the study.

Following planting, five permanent transects, each 25 feet (7.6 m) by 15 feet (4.6 m) were randomly established on both the topsoil and control sites. Each shrub rooted in a transect was recorded by species. Growth measurements were taken yearly beginning in 1980. These measurements included maximum plant height, crown spread, and annual herbage production (green weight).

Density and annual herbage production of the grasses and broadleaf herbs were measured by randomly establishing 10 subplots, each 2.28 ft^2 ($1\ m^2$), in both the topsoil and control plots. The number of grass, forb, and shrub seedlings occurring in the subplots were counted and recorded in 1980 and 1982. The subplots were also used to estimate ground cover of each species, litter, and bare soil.

Table 1.--Seed characteristics and species seeded at the Beacon Pit Mine, Nev., 1979.

Species seeded	Seed origin	Bulk rate planted lb/acre	Seed features: Germination percent	Purity percent	Number PLS[1]/lb	Number PLS/acre
GRASSES						
Agropyron cristatum 'Nordan'	Commercial	3	90	94	253,800	761,400
Agropyron riparium	Commercial	3	90	95	135,945	407,835
Elymus cinereus	Commercial	1	45	60	33,480	33,480
Oryzopsis hymenoides	Aberdeen PMC, Idaho	2	96	99	133,056	266,112
Psathyrostachys juncea	Commercial	2	90	92	138,276	276,552
BROADLEAF HERBS						
Linum lewisii	Sanpete Co., Utah	0.3	80	99	267,519	88,281
Medicago sativa	Commercial	2	87	99	181,150	362,301
Melilotus officinalis	Commercial	2	77	99	162,230	324,460
Sanguisorba minor	Commercial	2	95	99	52,093	104,186
SHRUBS						
Artemisia tridentata wyomingensis	Carey, Idaho	2.3	80	15	300,000	699,000
Atriplex canescens	Lincoln Co., Nevada	4	56	91	22,340	89,361
Atriplex confertifolia	Battle Mt., Nevada	0.3	10	86	7,287	2,404
Chrysothamnus nauseosus	Ada Co., Idaho	2	75	21	25,600	51,201
Kochia prostrata 'Immigrant'	Breeder seed	2	[2]66	65	154,847	309,695

[1]PLS = pure live seeds.
[2]Estimated value not confirmed by germination tests.

Factorial analyses of variance were used to compare the two treatments. Annual species densities were compared using a one-way analysis of variance. The results were considered to be significantly different at $P \leq 0.05$.

RESULTS AND DISCUSSION

Precipitation

During the study period 1979 to 1982, annual precipitation varied from 5.45 inches (13.8 cm) in 1982 to 11.09 inches (28.1 cm) in 1980 (table 2). During the season of plant establishment (1979), the site received 6.55 inches (16.6 cm) of moisture. The maximum moisture during any year occurred in the spring and summer months (March to June). Amounts of 7.6 inches (19.3 cm) and 6.18 inches (15.7 cm) were recorded during this seasonal period in 1980 and 1982, respectively. Although the annual amounts are quite low, the bulk of precipitation came during the early part of the growing season. Apparently sufficient moisture was received to initiate and sustain seed germination and seedling establishment.

Plant Establishment and Development

Grasses and broadleaf herbs.--Grass seeds of Fairway wheatgrass 'Nordan' (*Agropyron cristatum* [L.] Gaertn.), riparian wheatgrass (*Agropyron riparium* Scribn. & Sm.), Indian ricegrass (*Oryzopsis hymenoides* [R.&S.] Ricker in Piper), and Russian wildrye (*Psathyrostachys juncea* [Fischer] Nevski) germinated and seedlings emerged within the topsoil treatment in 1979. Although seedling counts were not recorded in 1979, grass seedlings were also observed in the control site in 1979. The topsoil provided a better seedbed for grasses than the soil of the control site. The percent ground cover of seeded grasses was significantly greater on the topsoil area ($P \leq .05$) for all years sampled (table 3).

The seeded grasses failed to provide measurable cover in the topsoil site until 1980 (table 3). Plant numbers remained unchanged, yet plant cover increased from 6 percent in 1981 to 15 percent in 1982.

Fairway wheatgrass was the only seeded grass to appear in the control treatment. By 1982, 4 years after seeding, this species provided only 1 percent

Table 2.--Seasonal and annual precipitation, Beacon Pit Mine, 1979 to 1982.

Season	Moisture received 1978-79	1979-80	1980-81	1981-82
	Inches			
October to February (winter)	2.07	3.09	1.72	2.00
March to June (spring-summer)	2.57	7.60	6.18	2.82
July to September (summer-fall)	1.91	.40	0.0	.63
Total (water year)	6.55	11.09	7.90	5.45

Table 3.--Mean annual ground cover for the topsoil and control treatments.

Species	Topsoil 1980	1981	1982	Control 1980	1981	1982
	Percent					
Seeded grasses	2	6	15	[1]T	1	1
Native grasses - perennials	0	T	1	0	0	0
Annual grasses	7	8	3	3	2	2
Native broadleaf forbs	0	T	0	1	0	T
Seeded broadleaf forbs	0	0	0	0	0	0
Seeded shrubs[2,3]						
Atriplex canescens	3	10	16	T	1	2
Atriplex confertifolia	0	0	0	0	0	0
Artemisia tridentata wyomingensis	1	3	5	0	0	0
Chrysothamnus nauseosus	2	6	9	1	1	2
Kochia prostrata	T	1	2	0	T	1
Total live cover	15	34	51	5	5	8
Litter	6	5	14	1	T	1
Bare ground	79	61	35	94	95	91

[1]T = trace amounts recorded.
[2]Shrub ground cover significantly different between the two treatments (P = 0.002).
[3]Shrub ground cover significantly different among species (P = 0.0426).

cover. Only a few new grass seedlings have been recorded in the control treatment since the site was planted.

Virtually no seeded broadleaf herbs established in either the topsoil or control areas. Prior to fencing in June 1979 rabbits severely grazed almost all young seedlings. The impact these animals had upon the survival of the seeded herbs is not fully known. Rabbits were observed to selectively graze the broadleaf seedlings.

Neither the topsoil or control treatments became infested with weeds. Cheatgrass brome provided 8 percent ground cover on the topsoil treatment in 1980, but only 3 percent in 1982 (table 3). On the control treatment, cheatgrass brome cover was 3 percent in 1980. This remained about the same in 1981 and 1982. The topsoil did not introduce or spread weeds. Although halogeton occurs along roadways and other disturbances, it did not invade either treatment site. The only native broadleaf forbs to appear in either study area were clasping pepperweed (Lepidium perfoliatum L.) and a few annual mustards (Sysymbrium spp.). Few native herbs are encountered adjacent to the mined site. Consequently, natural invasion has been seriously limited.

Seeded shrubs.--Numerous shrub seedlings established on the topsoil treatment (table 4). Significantly fewer plants ($P \leq 0.05$) were found in the control treatment for each shrub species planted and for each of the 3 years sampled.

Over 9,000 fourwing saltbush seedlings were recorded per acre (22 000/ha) in the topsoil treatment in the spring of 1980 (table 4). The number diminished to about 5,000 plants per acre (12 000/ha) in 1981 and 4,000 plants per acre (10 000/ha) in 1982. A total of 142 plants per acre (347/ha) were recorded on the control treatment in 1980. The number diminished to 117 per acre (286/ha) in 1982. Although significantly fewer ($P \leq 0.05$) fourwing saltbush seedlings were recorded in the control treatment, 82 percent of the plants counted in 1980 survived until 1982. During the same period, only 45 percent survival was recorded for this species in the topsoil treatment. Some plant mortality in the topsoil is to be expected due to the large number of seedlings established. As the community stabilizes and the plants reach maturity, some natural thinning will occur.

A significantly higher percentage of fourwing saltbush seedlings established on the topsoil treatment than any other seeded shrub. Approximately 10 percent of all viable fourwing seeds planted developed into established seedlings in 1980 (table 4). This figure dropped to 4.67 percent by 1982. This is a higher return than reported by previous investigators for shrub species planted on mine sites (Luke and Monsen, this proceedings), and is much higher than reported for antelope bitterbrush (Purshia tridentata [Pursh] D.C.) plantings in southwestern Idaho rangelands (Monsen and Shaw 1983). Only 0.16 percent of all viable fourwing saltbush seeds appeared as seedlings in the control treatment in 1980 (table 4). By 1982, the figure diminished slightly to 0.13 percent. Plummer (1977) and McArthur and others (1983) recognized differences among ecotypes of fourwing saltbush and suggested that considerable improvement in seedling vigor and other traits could be attained through the use of select types. The selection seeded in this study demonstrates excellent seedling vigor and seed germination potential.

In both the topsoil and control treatments, fourwing saltbush required about 4 years to become fully established, however, nearly all seeds germinated the first year. No recruitment of new seedlings was recorded in subsequent years.

Table 4.--Number of shrub seedlings and percent viable seeds to establish on the topsoil and control sites, Beacon Pit Mine, Nev.[1]

Species seeded	No. seeds planted PLS[2]/acre	Plant counts						Percentage of seeds to establish					
		Topsoil			Control			Topsoil			Control		
		1980	1981	1982	1980	1981	1982	1980	1981	1982	1980	1981	1982
		Number/acre						Percent					
Atriplex canescens	89,361	9,225	4,935	4,170	142	117	117	10.32	5.52	4.67	0.16	0.13	0.13
Atriplex confertifolia	2,404	40	14	0	0	0	0	.83	.58	0	0	0	0
Artemisia tridentata wyomingensis	699,000	1,555	1,567	1,569	0	0	0	.22	.22	.22	0	0	0
Chrysothamnus nauseosus	51,201	1,759	2,314	2,577	351	388	421	3.43	4.52	5.03	.68	.76	.82
Kochia prostrata	309,695	262	280	280	46	46	46	.08	.09	.09	.01	.01	.01
TOTAL		12,821	9,110	8,596	539	551	584						

[1]Significant difference (P= 0.001) between treatments, between species, and treatment species interaction.
[2]PLS = pure live seed.

Approximately 47 percent of all seedlings recorded on the topsoil site died between 1980 and 1981. By 1982, an additional 8 percent were lost. Thus, approximately 55 percent of the seedlings that emerged and persisted the first year died in the following 3 years. Losses now appear to be stabilizing; existing plants are large and healthy. More than 80 percent of the fourwing saltbush seedlings recorded on the control site in 1980 persisted as established plants in 1982.

The majority of fourwing saltbush plants to establish on the topsoil site grew rapidly and attained a mature stature in 4 years. Some fourwing saltbush seedlings and young plants grew erratically, but most grew faster than other seeded shrubs (fig. 1). Nearly 70 percent of all plants surviving in 1982 were taller than 10 inches (26 cm); 45 percent were taller than 20 inches (50 cm). Competition among seeded species appears to have suppressed the growth of some fourwing saltbush seedlings, but by 1982 only 8 percent of all existing plants were less than 5 inches (13 cm) in height.

Significantly fewer ($P \leq 0.05$) Wyoming big sagebrush seedlings established within the topsoil treatment than did fourwing saltbush (table 4). No Wyoming big sagebrush plants established on the control treatment. Most of the Wyoming big sagebrush seedlings that appeared on the topsoil site germinated the first year, however, establishment continued for perhaps 2 years. Nearly all plants counted in 1980 survived until 1982. The young plants grew rapidly, and did not appear to be suppressed by other shrubs. By 1982, few individuals were as large as the fourwing saltbush plants, yet most were over 11 inches (30 cm) tall (fig. 2). Plants are very uniform in height, yield, and vigor.

Only 0.22 percent of all viable Wyoming big sagebrush seeds planted into the topsoil area developed into established plants. The low return apparently is related to characteristics of the seedbed. Few seedlings emerged but those that appeared survived.

A number of rubber rabbitbrush seedlings established on the topsoil site by 1980 (table 4). The topsoil significantly ($P \leq 0.05$) increased the initial establishment of rubber rabbitbrush seedlings. Approximately four times more plants established initially in the topsoil area than in the control area.

The number of rubber rabbitbrush plants has increased annually from 1980-1982 on both planting sites (table 4). This apparently resulted from seeds being blown into the study areas from mature bushes of the surrounding plant community. Since 1980, rabbitbrush plant numbers have increased about 34 percent on the topsoil treatment, and over 73 percent within the control planting. Recruitment of new plants in the topsoil treatment continued even through approximately 13 percent of all 1- and 2-year-old plants die every year. Seedling mortality has not been detected in the control area. Approximately 3.44 percent of all viable rubber rabbitbrush seeds initially planted became established in the topsoil treatment (table 4). Only 0.68 percent establishment occurred in the control planting.

Figure 1.--Three-year-old plants of fourwing saltbush, rubber rabbitbrush, and 'Immigrant' forage kochia growing on the topsoil plot, Beacon Pit Mine, Nev.

Seedlings of 'Immigrant', a cultivar of forage kochia, established on both treatments (table 4); but the number of plants was significantly greater ($P \leq 0.05$) on the topsoil site. A low return of planted seeds was recorded for this species in both the topsoil (0.08 percent) and control (0.01 percent) treatments (table 4). All seedlings recorded in 1980 for both treatments survived through 1982, and were of similar size.

Seeds of 'Immigrant' forage kochia germinated the first spring after planting in both treatments; no new plants were recorded in subsequent years. Young seedlings developed slowly, yet after 2 years of growth the plants attained sufficient stature to become highly competitive.

Plants of surviving shrub species grew rapidly in the topsoil treatment. The total ground cover for all shrubs was 6 percent in 1980 (table 3). This increased to 32 percent by 1982. Shrubs that established in the control treatment also grew rapidly, yet the limited number of established plants furnish significantly lower total ground cover. Since 1980, the cover provided by shrubs in the topsoil treatment was double the figure recorded for all herbaceous plants (table 3).

Fourwing saltbush furnished the greatest cover of all seeded species for all years. The accelerated growth of fourwing saltbush, Wyoming big sagebrush, rubber rabbitbrush, and forage kochia is an important trait in providing an initial cover to disturbed sites (fig. 2).

Herbage Production

Topsoil was beneficial to the initial growth and herbage yield of the seeded shrubs and herbs; however, individual species responded differently (table 5). After 4 years, individual plants of fourwing saltbush, rubber rabbitbrush, and 'Immigrant' forage kochia were equally vigorous and nearly the same size on the control and topsoil sites.

Table 5.--Annual herbage production for topsoil and control treatments, Beacon Pit Mine, Nev.

Species	Topsoil 1981	Topsoil 1982	Control 1981	Control 1982
	- - - - -	lb/acre	- - - - -	
Seeded grass	584	498	79	79
Annual grass	5	12	12	12
Native forbs	6	0	6	0
Seeded forbs	0	0	0	0
Seeded shrubs[1]				
Atriplex canescens	451	1357	40	86
Artemisia tridentata wyomingensis	122	295	0	0
Chrysothamnus nauseosus	150	594	26	248
Kochia prostrata	64	34	13	75
Atriplex confertifolia	2	0	0	0
TOTAL	1384	2790	184	443

[1]Shrub production significantly different between the two treatments ($P = 0.0401$).

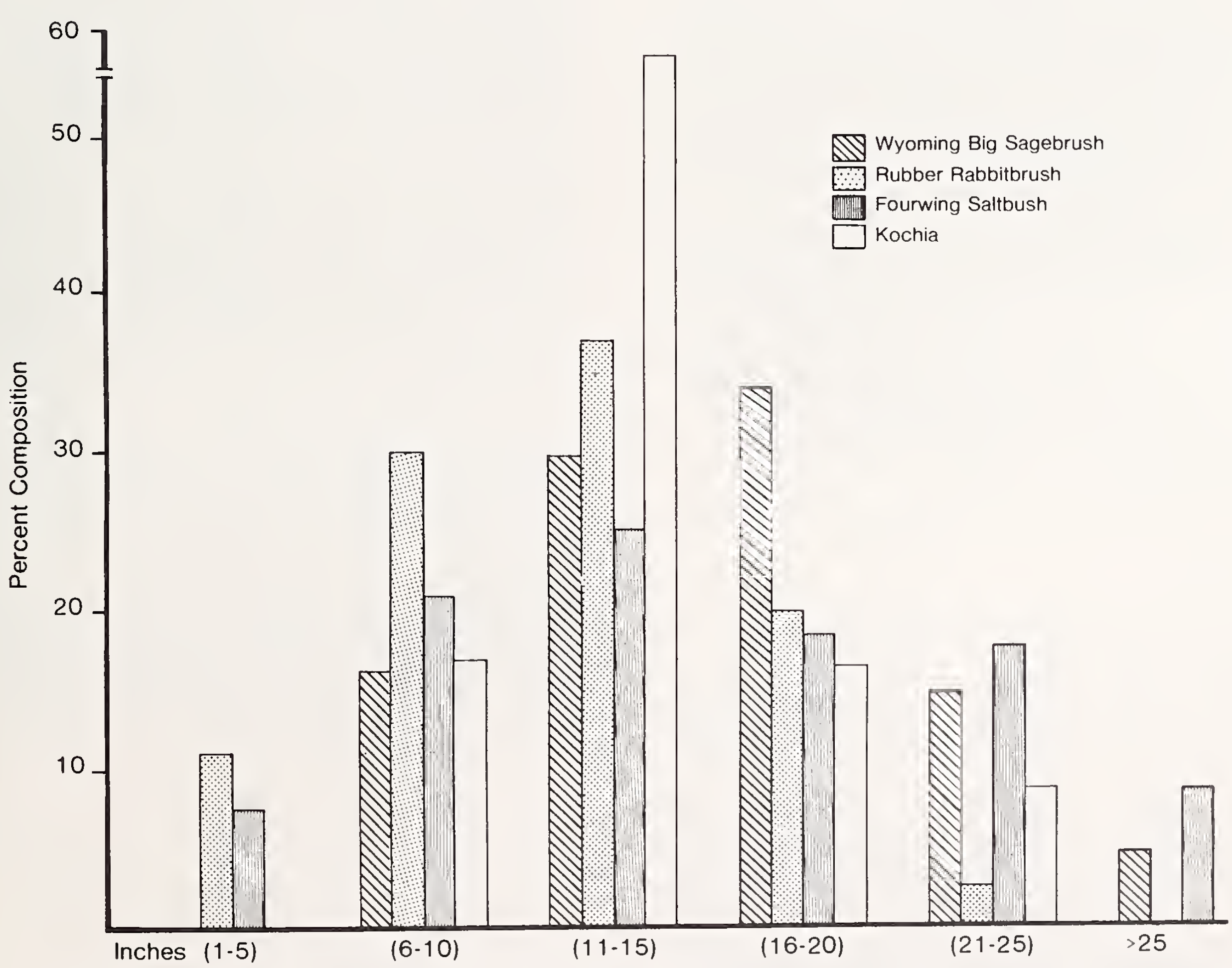

Figure 2.--Percent composition of plants by height class for 4-year-old shrubs growing on top soil.

A greater number of fourwing saltbush, Wyoming big sagebrush, and rubber rabbitbrush plants established on the topsoil site, which influenced the total herbage produced. With the exception of 'Immigrant' forage kochia, the topsoil treatment resulted in a significantly greater ($P \leq 0.05$) amount of herbage produced than the control site (table 5). Differences were significant for 1981 and 1982. Established plants of fourwing saltbush and rubber rabbitbrush were quite vigorous in both the topsoil and control treatments, and produced a large volume of annual growth.

About equal numbers of 'Immigrant' forage kochia plants established on each treatment site. By 1982, plants in the control plot produced nearly twice the amount of annual herbage as those on the topsoil site. This shrub appeared well adapted to the harsh soil conditions created by mining.

Shrubs were much more productive in both treatments than the seeded herbs. Although the topsoil significantly benefited ($P \leq 0.05$) the production of herbs, total production of the understory species was considerably less than the combined yield of the shrubs. Forage produced by shrubs was greater in all years sampled than grass yield. This is an important aspect to consider in providing immediate ground cover and forage production.

Shrub-Herb Mixed Seeding

Effects of mixing and seeding shrubs with grasses and broadleaf herbs were not fully determined in this study. Clarke and DePuit (1981), and DePuit and others (1980) found that when seeded together competition from grass seedlings can be detrimental to slower developing shrubs. Although topsoil increased grass density at the Beacon Pit Mine, the ground cover of the seeded grasses remained less than 15 percent. Apparently this amount of herbaceous cover was not detrimental to shrub seedling establishment and survival. Shrubs were much better adapted to the control treatment than the seeded herbs. Very few herbaceous plants became established on the control site to compete with the shrubs. Planting shrubs on semiarid mine wastes is a viable means of establishing plant cover, particularly on sites where herbs are difficult to establish.

Cultipack Seeding

The Brillion cultipack seeder was effective in seeding the shrub-herb mixture. The machine adequately planted the larger seeds of fourwing saltbush and rubber rabbitbrush. The long brittle achenes of rubber rabbitbrush were not damaged by the seeder. The machine was also capable of seeding the small seeds and chaff or trashy material of Wyoming big sagebrush. Small seeds of Wyoming big sagebrush and 'Immigrant' forage kochia were uniformly dispersed. A low return of the small-seeded species suggests that these seeds were not correctly planted, but shrub density of the small-seeded plants was acceptable.

CONCLUSIONS

Seeded grasses were not well adapted to the mine wastes. Few grass seedlings germinated in the control treatment. Topsoil significantly improved the seedbed condition for grasses and improved herbage production. Seeded broadleaf herbs failed to establish in either treatment, but rabbit grazing may have accounted for the death of all seedlings.

The seeded shrubs of fourwing saltbush, rubber rabbitbrush, and 'Immigrant' forage kochia all are well adapted to both the topsoil and control treatments. Topsoil significantly improved the seedbed condition for all seeded shrubs, yet plants also established in the control area. The collection of fourwing saltbush from Panaca, Lincoln Co., Nev. that was planted at the mine site demonstrated excellent seedling survival and growth. A considerably higher return of planted seeds occurred with this species than any other seeded shrub. This selection appears promising for mine reclamation in semiarid regions.

Rubber rabbitbrush is adapted to the mine disturbances, but did not establish as well as fourwing saltbush from direct seeding. However, the plant spread quickly from natural seeding, and was able to establish on the rough, barren surfaces throughout the control and topsoil sites.

The cultivar of forage kochia, 'Immigrant', appears well suited to mine sites. Only scattered plants established in both treatments, but low seed viability may have accounted for the variable stand. Established plants grew very well in both treatments, and natural spread appears highly possible.

Seedlings of Wyoming big sagebrush established only on the topsoil site. This may be due to the seedbed conditions of the control site or the lack of adaptability of the sage to the mine wastes.

All seeded species of shrubs, except shadscale saltbush, grew quickly and were compatible with seeded herbs. Shrubs were better adapted to the mine disturbances than the herbs, and can be used to provide an immediate, yet effective cover.

PUBLICATIONS CITED

Aldon, Earl F. Long-term plant survival and density data from reclaimed southwestern coal mine spoils. Great Basin Naturalist. 41(3): 271-273; 1981.

Aldon, Earl F.; Pase, Charles P. Plant species adaptability on mine spoils in the Southwest: a case study. Res. Note RM-393. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1981. 3p.

Clarke, Joseph W.; DePuit, Edward J. Analysis of direct seeding methods for establishment of select-native shrub species on minesoils in southeastern Montana. In: Stelter, L. H.; DePuit, E. J.; Mikol, S. A., technical coordinators. Shrub establishment on disturbed arid and semi-arid lands: Proceedings 1980 December 2-3; Laramie, WY. Cheyenne, WY: Wyoming Game and Fish Department; 1981: 89-103.

Cundell, A. M. The role of microorganisms in the revegetation of strip-mined land in the western United States. J. Range Manage. 30(4): 299-305; 1977.

Currie, Pat O.; White, Richard S. Drought survival of selected forage grasses commonly seeded in the Northern Great Plains. Can. J. Plant Sci. 62: 949-955; 1982.

DePuit, Edward J.; Coenenberg, Joe G. Methods for establishment of native plant communities on topsoiled coal strip mine spoils in the Northern Great Plains. Reclamation Rev. 2: 75-88; 1979.

DePuit, Edward J.; Coenenberg, Joe G.; Skilbred, Chester L. Establishment of diverse native plant communities on coal surface-mined land in Montana as influenced by seeding method, mixture, and rate. Res. Report 163. Bozeman, MT: Montana State University, Reclamation Research Unit, Montana Agricultural Experiment Station; 1980. 64 p.

Ferguson, Robert B.; Frischknecht, Neil C. Shrub establishment on reconstructed soils in semiarid areas. In: Stelter, L. H.; DePuit, E. J.; Mikol, S. A., technical coordinators. Shrub establishment on disturbed arid and semi-arid lands: Proceedings; 1980 December 2-3; Laramie, WY. Cheyenne, WY: Wyoming Game and Fish Department; 1981: 57-63.

Gomm, F. B. Forage species for the northern Intermountain Region: a summary of seeding trials. Tech. Bull. 1479. Hyattsville, MD: U.S. Department of Agriculture, Agricultural Research Service and Montana Agricultural Experiment Station; 1974. 307 p.

Holechek, Jerry L.; DePuit, Edward J.; Coenenberg, Joe G.; Valdex, Raul. Fertilizer effects on establishment of two seed mixtures on mined land in southeastern Montana. J. Soil and Water Conserv. 36(4): 241-244; 1981.

Howard, Gene S.; Rauzi, Frank; Schuman, Gerald E. Woody plant trials at six mine reclamation sites in Wyoming and Colorado. SEA Production Res. Report 117. Washington, DC: U.S. Department of Agriculture; 1979. 14 p.

Lawrence, T.; Troelsen, J. E. An evaluation of 15 grass species as forage crops for southwestern Saskatchewan. Can. J. Plant Sci. 44: 301-310; 1964.

Lawrence, T. Clarke. Intermediate wheatgrass. Can. J. Plant Sci. 61: 467-469; 1981.

McArthur, E. D.; Stevens, R.; Blauer, A. C. Growth performance comparison among 18 accessions of fourwing saltbush (Atriplex canescens) at two sites in central Utah. J. Range Manage. 36(1): 78-81; 1983.

Monsen, Stephen B.; Shaw, Nancy L. Seeding antelope bitterbrush with grass on south-central Idaho rangelands--a 39-year response. In: Tiedemann, Arthur R.; Johnson, Kendall L., compilers. Proceedings, research and management of bitterbrush and cliffrose in western North America; 1982 April 13-15, Salt Lake City, UT. Gen. Tech. Report INT-152. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1983: 126-136.

Nicholas, Paula J.; McGinnies, William J. An evaluation of 17 grasses and 2 legumes for revegetation of soil and spoil on a coal strip mine. J. Range Manage. 35(3): 288-293; 1982.

Plummer, A. P. Revegetation of disturbed Intermountain area sites. In: Thames, J. L., ed. Reclamation and use of disturbed land in the Southwest. Tucson, AZ: University of Arizona Press; 1977: 302-309.

Plummer, A. P.; Christensen, D. R.; Monsen, S. B. Restoring big-game range in Utah. Utah Publ. No. 68-3. Salt Lake City, UT: Utah Division of Fish and Game; 1968. 183 p.

Stevens, Richard; Moden, Walter L., Jr.; McKenzie, Dan W. Interseeding and transplanting shrubs and forbs into grass communities. Rangelands. 3(2): 55-58; 1981.

Vallentine, John F. Range development and improvements. 2d ed. Provo, UT: Brigham Young University Press; 1980. 545 p.

Van Epps, Gordon A.; McKell, Cyrus M. Revegetation of disturbed sites in the salt desert range of the Intermountain West. Utah Agricultural Experiment Station Land Rehabilitation Series No. 5. Logan, UT: Utah State University; 1980. 37 p.

Wilson, D. B.; Smoliak, S. Greenleaf pubescent wheatgrass. Can. J. Plant Sci. 57: 289-291; 1977.

In: Tiedemann, Arthur R.; McArthur, E. Durant; Stutz, Howard C.; Stevens, Richard; Johnson, Kendall L., compilers. Proceedings--symposium on the biology of Atriplex and related chenopods; 1983 May 2-6; Provo, UT. General Technical Report INT-172. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 309 p.

ATRIPLEX SUCKLEYI (Torrey) Rydb.: A NATIVE ANNUAL PLANT FOR REVEGETATING BENTONITE MINE SPOILS

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ABSTRACT: Rillscale (Atriplex suckleyi [Torrey] Rydb.) is a plant that may have potential for revegetating bentonite mine spoils following spoil modifications. Sawdust and gypsum amendments were effective for improving spoils as a plant growth medium when applied in the fall. Spring applications of sawdust were less effective and spring applications of gypsum were ineffective. Fertilizers (NPK) generally had no effect on plant growth.

INTRODUCTION

In the selection of plant species for revegetation of mined lands, several factors must be considered, including climate, soil or spoil characteristics, and postreclamation land use plans. On sites harsh to plant growth, it may be necessary to use species representing lower successional stages.

Bentonite mine spoils of the northern Great Plains represent one example of harsh sites that pose several problems for revegetation. Spoils are typically saline-sodic, with an electrical conductivity of more than 9 mmhos/cm and a sodium adsorption ratio of 20-56 (Bjugstad and others 1981; Yamamoto and Uresk 1981). High percentages of shrink-swell clays dominate the spoils and can result in damage to root systems. Spoils may also be low in nitrogen, although levels of other nutrients appear adequate. Annual rainfall ranges from 9 to 24 inches (25 to 60 cm). Moisture is deficient throughout most of the year (Thornburg and Fuchs 1978); up to 75 percent of annual precipitation is received from April to September. Topsoil above bentonitic shales is characteristically shallow and poorly developed.

Efforts to establish vegetation on bentonite mine spoils have generally failed. These efforts have included the use of grasses, forbs, shrubs, and trees, with many of these species being considered tolerant to salt. Yamamoto and Uresk (1981) conducted a greenhouse study on bentonite mine spoil and tested eight species of drought- and alkaline-tolerant trees, forbs, and shrubs to determine if certain spoil amendments might improve survival rates. They found that sawdust was especially effective for increasing survival of fourwing saltbush (Atriplex canescens [Pursh] Nutt.), rubber rabbitbrush (Chrysothamnus nauseosus [Pall.] Britt.), big sagebrush (Artemisia tridentata Nutt.), winterfat (Ceratoides lanata [Pursh] Moq.), Russian-olive (Elaeagnus angustifolia L.), and yarrow (Achillea lanulosa Nutt.).

Sieg and others (1983), in a study of biota of bentonite mine spoils in Montana, found a spreading annual chenopod, Atriplex suckleyi (Torrey) Rydb., commonly called rillscale, to be the dominant, native invader. Rillscale is limited in range to the northern Great Plains. It has been noted for its occurrence on clayey, saline lands "where no other plant species seem to grow" (Frankton and Bassett 1970). The plant may grow to 1 foot (39 cm) in height and has an apparent plastic morphology on bentonite mine spoils. As a member of the genus Atriplex, highly valued among rangemen, rillscale may be useful as a forage plant.

In view of its success on bentonite mine spoils, rillscale was selected as an appropriate species for use as an indicator of the value of amendments for improving bentonite mine spoils as plant growth media. Also of interest was the potential of rillscale for use in revegetation of bentonite mine spoils. By acting as a pioneering species on spoils, rillscale may have important stabilizing effects. Also, it may modify spoils in a way that would eventually prove conducive to the establishment, survival, and growth of plant species representing higher successional stages.

The objectives of this study were to evaluate the effects of (1) spoil amendments (gypsum, sawdust, and fertilizer) on production, height, and cover of rillscale on bentonite mine spoils; (2) season of amendment on production, height, and cover of rillscale on bentonite mine spoils; (3) seeding on the density of rillscale on the amended spoil; and (4) season of seeding on the density of rillscale on the amended spoils.

The study area was just west of the central Black Hills on the Mowry Shale formation, approximately one mile northwest of Upton, Wyo. Sites on the property had been mined at various times for more than 30 years,

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but not later than 1968.[1] Elevation was approximately 4,230 feet (1 290 m). Average annual precipitation was about 14 inches (35 cm) (NOAA 1981). Vegetation is characteristically big sagebrush-grass interspersed with stands of ponderosa pine (Pinus ponderosa Laws). The area provides forage for many species of wildlife, including antelope (Antilocapra americana americana [Ord]) and mule deer (Odocoileus hemionus hemionus [Rafinesque]), as well as for livestock.

METHODS

The experimental design was a 2^3 factorial arrangement, with each of three spoils amendments at two levels, one level the absence of the amendment and the other the presence of the amendment. The three amendments were: (1) gypsum, applied at the rate of 14 tons per acre (31 metric tons/ha); (2) fertilizer, added at the rate of 100 pounds nitrogen per acre (113 kg/ha), 18 pounds phosphorus per acre (20 kg/ha) and 45 pounds potassium per acre (50 kg/ha); and (3) sawdust, added at the ratio of one part sawdust to two parts spoil (by volume), with nitrogen corresponding to 0.6 percent of sawdust (by weight).

The study site was rototilled to a depth of approximately 2 inches (5 cm).

Gypsum and sawdust amendments were manually incorporated into tilled spoil, while fertilizer amendments were applied on the surface. Eight combinations of the three amendments were replicated six times, each replication representing one randomized block, to give a total of 48 plots. Three of these replications were seeded and three were left unseeded, for comparison of seeded and volunteer growth. One set of 48 plots was tilled, amended, and seeded in September 1981; another set of 48 plots was tilled, amended, and seeded in April 1982.

Seeds were obtained from sites along the Montana-Wyoming border during late summer 1980. Approximately 20 live seeds per square inch (3 seeds/cm^2) were planted in each seeded plot. The weight of seed needed to achieve this density was calculated from total percentage germination and seed density determinations made within 6 weeks before planting. Seed was broadcast on the surface and lightly covered with spoil.

Maximum plant height and stem density were measured and recorded on five 4- X 4-inch (10-cm^2) quadrats in each plot beginning in mid-May and continuing at 3-week intervals throughout the 1982 growing season. The quadrats were located at 12-inch (30-cm) intervals on a transect running the length of each plot. Total canopy cover was visually estimated for each plot, using six cover classes (Daubenmire 1959). Aboveground production for each plot was harvested from the entire plot at the end of the 1982 growing season, dried at 131°F (55° C), and weighed.

Statistical analyses included a comparison of production, height, and cover on seeded plots among amendment combinations and planting dates, using factorial analysis of variance. A T-test was used to compare plant density between seeded and unseeded plots.

RESULTS AND DISCUSSION

Gypsum and sawdust were effective in increasing ($p = 0.05$) production, height, and cover of rillscale only on those spoils amended and seeded in the fall of 1981 (table 1). On spoils amended and seeded in the spring of 1982, the sawdust increased cover, but not height or production, while the gypsum had no effect on production, height, or cover. Fertilizer reduced ($p = 0.05$) height of rillscale on plots amended and seeded in the spring of 1982, and had no effect on plants within treatment plots amended and seeded in the fall of 1981 (table 1). Fertilizer, applied either in the spring or fall, did not affect production or cover of rillscale.

Although amendment effects were generally independent of one another, an interaction between fertilizer and sawdust on height of rillscale when these amendments were added in the spring, was revealed. This interaction was expressed as lower than expected height-increasing effects of sawdust when fertilizer was also added and lower height-decreasing effects of fertilizer when sawdust was also added. This interaction may have caused height means, as presented in table 1, to be somewhat biased, with the mean for height with sawdust being slightly underestimated and the mean for height with fertilizer being slightly overestimated.

Height and cover of rillscale on plots amended and seeded in the fall of 1981 were greater ($p = 0.05$) than on plots amended and seeded in the spring of 1982 (table 1). However, production did not differ between these two sets of plots. As an annual, rillscale probably initiates growth very early in the spring, before field conditions allow spring amendment and seeding. This would explain the decreased height and cover of rillscale on plots that had been tilled, amended, and seeded in the spring of 1982 as compared to the fall. Annual precipitation for 1982 was 42 percent above normal (May through August) providing inordinately favorable growing conditions for both spring and fall plantings.

[1] Personal communication with R. Sieg, American Colloid Co., Rapid City, South Dakota, Aug. 1982.

Table 1.--Production, height, and cover of rillscale during the 1982 growing season as affected by amendments of gypsum, sawdust, and fertilizer, and by season of application of these amendments.

Amendment	Production Fall	Production Spring	Height Fall	Height Spring	Cover Fall	Cover Spring
	--Pounds/Acre--		--Inches--		--Percent--	
All amendments	[1]1462 a	1096 a	3.9 a	2.0 b	42 a	26 b
Gypsum						
without	[2]955 a	1165 a	3.2 a	2.2 a	31 a	29 a
with	1813 b	972 a	4.6 b	1.9 a	53 b	23 a
Sawdust						
without	843 a	1003 a	2.9 a	1.8 a	28 a	19 a
with	1561 b	1134 a	4.9 b	2.2 a	56 b	33 b
Fertilizer						
without	1973 a	1187 a	3.6 a	2.5 b	37 a	29 a
with	1695 a	949 a	4.1 a	1.6 a	47 a	23 a

[1]Numbers in each spring-fall comparison that are followed by the same letter are not significantly different (p = 0.05).

[2]Numbers in a column for each amendment category that are followed by the same letter are not significantly different (p = 0.05).

The mid-May density of plants on seeded plots was 131 plants/ft^2 (1,323 plants/m^2) and exceeded (p = 0.05) density of plants on unseeded plots (59 plants/ft^2, 596 plants/m^2) on spoils amended and seeded in the fall of 1981. Seeding of amended plots in the spring of 1982 did not increase the density of plants above the density of plants on amended plots that were not seeded. Density of spring-amended plots averaged 11 plants/ft^2 (111 plants/m^2).

CONCLUSIONS

The addition of fertilizer to bentonite mine spoils was not shown to be effective, regardless of season. Additions of sawdust and gypsum in the fall were shown to be effective for improving spoils as plant growth media, primarily because of their effects on physical characteristics of the spoils. Increased production and cover resulting from the addition of sawdust or gypsum are expected to have a significant effect on spoil protection and stabilization, and on the rate of soil development over spoils.

The timing of spoils modifications is important. Fall amendments and seeding were shown to be more effective than spring amendments and seeding. Spring amendments had no effect on production, height, or cover of rillscale with two exceptions: (1) spring additions of sawdust resulted in increased cover of rillscale, and (2) spring additions of fertilizer resulted in decreased height of rillscale. Fall amendment and seeding were generally found to be more practicable than spring amendment and seeding because of more favorable weather conditions. Fall additions of gypsum and sawdust are, therefore, recommended for the improvement of bentonite mine spoils as plant growth media. When fall applications are not practicable and cover is critical, sawdust should be applied in the spring. Increased seedling density was observed when seed was added in the fall, but not when seed was added in spring. This effect is attributed to the climatic requirements of rillscale for germination and establishment. Seeding should be done in the fall where increased density of rillscale is desired.

Rillscale responded to spoils amendments and seeding with increased production, height, and density. The potential of rillscale for use as a revegetating species on bentonite mine spoils is thus supported by these results.

PUBLICATIONS CITED

Bjugstad, Ardell J.; Yamamoto, Teruo; Uresk, Daniel W. Shrub establishment on coal and bentonite clay mine spoils. In: Proceedings, shrub establishment on disturbed arid and semi-arid lands

symposium; 1980 December 2-3; Laramie, WY. Cheyenne, WY: Wyoming Fish and Game Department; 1981: 104-122.

Daubenmire, R. A canopy-coverage method of vegetational analysis. Northwest Sci. 33(1): 43-64; 1959.

Frankton, C.; Bassett, I. J. The genus *Atriplex* (Chenopodiaceae) in Canada. II. Four native western annuals: *A. argentea*, *A. truncata*, *A. powelli*, and *A. diocia*. Can. J. Bot. 48: 981-989; 1970.

U.S. Department of Transportation, National Oceanic and Atmospheric Administration. Wyoming climatological data: Annual summary, 1981-1982.

Sieg, Carolyn Hull; Uresk, Daniel W.; Hansen, Richard M. Plant-soil relationships on bentonite mine spoils and sagebrush-grassland in the northern High Plains. J. Range Manage. 37: 289-294; 1983.

Thornburg, A. A.; Fuchs, S. H. Plant materials and requirements for growth in dry regions. In: Proceedings, reclamation of drastically disturbed lands; 1976 August 9-12; Wooster, OH. Madison, WI: American Society of Agronomy-Crop Science Society of America-Soil Science Society of America; 1978:419.

U.S. Department of Transportation, National Oceanic and Atmospheric Administration. Wyoming climatological data: Annual summary, 1981. Asheville, NC: U.S. Department of Transportation, National Oceanic and Atmospheric Administration; 1982. p. 5

Yamamoto, T.; Uresk, D. W. Growth of plants on bentonite spoils under greenhouse conditions. In: Abstracts of 32nd annual meeting of the Society for Range Management; 1981 February 12-15; Casper, WY: Denver, CO. Society for Range Management; 1981: 55.

In: Tiedemann, Arthur R.; McArthur, E. Durant; Stutz, Howard C.; Stevens, Richard; Johnson, Kendall L., compilers. Proceedings--symposium on the biology of *Atriplex* and related chenopods; 1983 May 2-6; Provo, UT. General Technical Report INT-172. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 309 p.

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This proceedings, second in a series of publications of wildland shrub symposia, brings together current knowledge of plants belonging to the chenopod family. Topics addressed by the 46 papers include distribution, systematics, genetics, ecological relationships, physiology, seed technology, animal relationships, and revegetation techniques.

KEYWORDS: Chenopodiaceae, Atriplex, Ceratoides, Kochia, distribution, systematics, genetics, ecology, physiology, seeds, insects, grazing use, wildlife use, revegetation, mined land reclamation

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